Issued January 8, 1908.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 101.

A. D. MELVIN, CHIEF OF BUREAU.

THE AVAILABLE ENERGY OF RED CLOVER HAY.

INVESTIGATIONS WITH THE RESPIRATION CALORIMETER

IN COOPERATION WITH

THE PENNSYLVANIA STATE COLLEGE AGRICULTURAL EXPERIMENT STATION.

BY

HENRY PRENTISS ARMSBY AND J. AUGUST FRIES.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., August 30, 1907.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin 101 of this Bureau a manuscript entitled "The Available Energy of Red Clover Hay," by Dr. H. P. Armsby, and J. August Fries. This paper reports further experiments conducted with the respiration calorimeter by the Pennsylvania Agricultural Experiment Station in cooperation with this Bureau. Similar experiments in connection with timothy hay, red clover hay, and maize meal have previously been reported in Bulletins 51 and 74 of this Bureau.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

State College, Pa., *July 1, 1907.*

Sir: I have the honor to submit herewith a report upon the third series of cooperative experiments with the respiration calorimeter at the Pennsylvania State College.

As in previous experiments, the details of the work have been in charge of Mr. J. August Fries, assistant in animal nutrition. Mr. Fries has been assisted by Messrs. W. W. Braman, A. K. Risser, T. M. Carpenter, R. E. Stallings, J. B. Robb, and John Foster, while the necessary chemical work was carried out by the chemical division of the experiment station under the general direction of Dr. William Frear.

Very respectfully,
Henry Prentiss Armsby,
Expert in Animal Nutrition.

Dr. A. D. Melvin,
Chief of the Bureau of Animal Industry.

CONTENTS.

ILLUSTRATIONS.

THE AVAILABLE ENERGY OF RED CLOVER HAY.

INTRODUCTION.

The experiments reported in Bulletin 74 of this Bureau upon "Energy values of red clover hay and maize meal" gave somewhat questionable results for the net available energy of red clover hay. From a comparison of the first and second periods of that experiment an availability of 36.42 per cent was computed, but it was pointed out in reporting this result that the figures were comparatively low and must be accepted with considerable reserve. The experiment here reported, which was carried out during the winter of 1903–4, is a repetition of that portion of the previous experiment relating to clover hay, but upon a more extended scale, and shows that the doubt expressed as to the accuracy of the earlier figure for availability was apparently fully justified.

The general plan of the experiment was to feed the animal three different amounts of red clover hay, all less than the maintenance requirement, and to investigate the metabolism of the animal upon each ration at two different temperatures. Unfortunately, as appears in the following pages, the range of temperature within which the respiration calorimeter could be used was so limited that the experiments failed to afford any decisive results regarding the influence of temperature upon metabolism.

The animal used was the same grade Shorthorn steer which served in the experiments of 1901–2 and 1902–3. At the time of these experiments he was approximately 5 years old.

DESCRIPTION OF EXPERIMENTS.

ANALYTICAL METHODS.

The methods employed for the analysis of the feed and the excreta were substantially those recommended by the Association of Official Agricultural Chemists. The nitrogen of the feces was determined in the fresh material by König's method and the nitrogen of the urine by direct oxidation by the Kjeldahl method. In the computation of proteids from proteid nitrogen the conventional factor 6.25 was used both for the clover hay and for the feces. The nonproteids were computed from the nonproteid nitrogen by multiplication by

4.7, the factor for asparagin. Carbon and hydrogen were determined by combustion with cupric oxide in a current of air followed by oxygen. The heats of combustion of the feed and excreta were determined by means of the Atwater-Hempel bomb calorimeter.

THE FEEDS.

The hay used was red clover hay grown on the college farm in the summer of 1903. It was secured without rain and retained most of the leaves on the stems. On November 30 about a ton of this hay was run through a feed cutter and cut to lengths of about 7 to 10 centimeters. From the mass of cut hay two separate samples were taken by the same method as in previous experiments.[a] During the progress of the experiments a sample of hay was also taken at the time of weighing out for each period, as described in subsequent pages, or three samples in all. The following table shows the composition of the dry matter of the several samples, the generally close agreement of the results indicating that the method of sampling was sufficiently accurate:

TABLE 1.—*Composition of clover hay (dry matter).*

Constituents and energy.	General samples.			Samples taken during experiments.		
	A.	B.	Average.	Period I.	Period II.	Period III
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	6.57	.....	.....	6.92	7.11	6.84
Proteids	11.69	10.66	11.18	12.11	11.82	11.84
Nonproteids	0.78	0.99	0.89	1.35	1.63	1.45
Crude fiber	28.78	.....	.....	28.45	28.02	28.83
Nitrogen-free extract	49.25	.....	.....	47.83	47.98	47.69
Ether extract	2.93	.....	.....	3.33	3.44	3.35
	100.00	.....	.....	100.00	100.00	100.00
Total carbon	46.43	46.04	46.24	46.57	46.24	46.17
Total nitrogen	2.039	2.042	2.041	2.223	2.238	2.205
Proteid nitrogen	1.872	1.818	1.845	1.935	1.890	1.895
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Heat of combustion, per gram	4.4932	4.4906	4.4919	4.4903	4.4888	4.478

PERIODS AND RATIONS.

On November 4, 1903, the steer was placed in a stall in the station barn and fed 6.35 kilograms of mixed clover and timothy hay with a little grain until December 2, 1903, when the grain ration was withdrawn. On December 26 the feeding of the ration used for the first period of the experiment was begun, and on January 2 the animal was transferred to a stall in the calorimeter building. The hay was given in equal amounts at about 6 p. m. and 6 a. m. Each period covered twenty-one days, of which the first eleven were regarded as a pre-

[a] Bulletin 51, Bureau of Animal Industry, p. 10.

liminary period and the last ten as constituting the digestion period proper. In view of the fact that all the rations were less than the maintenance requirement, intervals of seven days were interposed between the successive periods, during which the animal was removed to the station barn and fed a ration of 14 pounds of hay and 10 pounds of grain daily. The table shows the exact dates of the several periods and the rations fed.

TABLE 2.—*Dates and rations.*

Period.	Interval.	Preliminary period.	Digestion period.	Hay fed per diem.
				Kilograms.
I	December 26 to January 1	January 2 to 12	January 13 to 22	3.4
II	January 23 to January 29	January 30 to February 9	February 10 to 19	5.9
III	February 20 to February 26	February 27 to March 8	March 9 to 18	4.8

The animal was watered daily at about 1 p. m., with the exception of the days when he was in the calorimeter and the day before and after, when water was given immediately before the morning feeding.

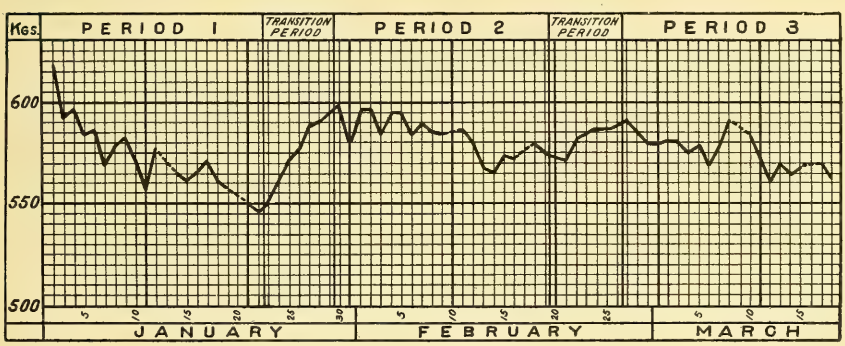

DIAGRAM 1.—Live weights of animal.

LIVE WEIGHTS.

The animal was weighed daily at 1 p. m., immediately before watering and also immediately after, the difference being taken as representing the amount of water consumed. On the days when the animal was in the calorimeter the weight was taken immediately before entering and immediately after leaving the apparatus. The figures for live weight and amount of water consumed are given in Table I of the Appendix in connection with the weights of the excreta, and the live weights are shown graphically on Diagram 1.

DETERMINATIONS OF DIGESTIBILITY.

WEIGHING AND SAMPLING OF FEED.

The hay for each period was weighed out in advance in cloth bags, a day's ration in a bag. In filling the bags the mass of hay was worked into from the side, taking all the material down to the floor. While the bags were being filled, two or three portions of the hay were taken from each bag and set aside in a covered vessel. Immediately after the weighing this was rapidly chopped in a meat chopper, thoroughly mixed, and a sample of 1,000 to 1,500 grams was taken to the laboratory in a covered vessel for determination of dry matter and of the composition of the latter, with the results shown in Table 1.

TREATMENT OF SAMPLES.

The samples when received at the laboratory were immediately weighed, air-dried at a temperature of about 60° C., allowed to hang at ordinary temperature in heavy paper bags for several days, and then ground in a mill as rapidly as practicable, and preserved in sealed bottles. The analyses were made as promptly as practicable, although not in all cases immediately.

HOURS OF FEEDING.

As a matter of convenience in arranging for the work with the respiration calorimeter, the hour of 6 p. m. was taken as the beginning of the day. Approximately one-half of the hay was given at this time and the remainder twelve hours later.

COLLECTION AND SAMPLING OF EXCRETA.

The animal was provided with the rubber duct described and illustrated in a previous publication[a] for the collection of the feces and with the ordinary urine funnel. These were worn both during the preliminary days and during the digestion period proper, but not during the intervals between the periods. The apparatus served its purpose excellently, loss of excreta occurring in but few instances.

During the digestion period the excreta were weighed promptly at the end of each twenty-four hours, and a sample was drawn after thorough mixing and taken at once to the laboratory for treatment. There a uniform percentage of the total excretion was set aside for a composite sample, chloroform being used as a preservative. At the close of the period these composite samples were thoroughly mixed. In the feces the total nitrogen in the fresh substance was determined by the König method, while a portion of the composite sample was also air-dried at about 60° C. and the air-dry sample subjected to the usual method of analysis, including the determination of its heat of combustion and of carbon and hydrogen. In the mixed sample of

[a] Pennsylvania Experiment Station Bulletin 42, p. 74.

urine the total nitrogen, total carbon, hydrogen in organic combination, and heat of combustion were determined.

DIGESTIBILITY OF RATIONS.

Period I (January 13–22, 1904).

The live weights of the animal and the weights of excreta are shown in Table I of the Appendix. The following table shows for the digestion period proper, the weight of hay fed, of hay eaten, and of the portions remaining uneaten; the weight of excreta collected, of the portions spilled, and of the total excretion; and the corresponding weights and percentages of dry matter found.

TABLE 3.—*Feed and excreta—Period I.*

Feed and excreta.	Fresh weight.	Dry matter.	
	Grams.	*Per cent.*	*Grams.*
Hay:			
Total in 10 days	34,000.0	86.32	29,348.8
Uneaten January 21[a]	63.0	3.33	2.1
Uneaten January 22	15.9	83.65	13.3
Total uneaten	78.9		15.4
Eaten	33,921.1		29,333.4
Eaten per day	3,392.1		2,933.3
Feces:			
Collected in 10 days	54,937.0		11,256.6
Spilled in calorimeter January 14	109.1	29.36	34.0
Adhering to duct January 14	18.0		6.1
Spilled in stall January 16	1.2		1.1
Spilled in calorimeter January 22	25.1	41.52	10.4
Spilled in stall January 22	36.6	28.44	10.4
Total excretion	55,127.0		11,318.6
Daily excretion	5,512.7		1,131.8

[a] Including water spilled in feed box.

The composition of the dry matter of the feeding stuffs has already been stated in Table 1, and that of the dry matter of the feces is shown in Table II of the Appendix.

Basing the computation upon the above average weights, the digestibility of the hay, as shown in Table III of the Appendix, was as follows:

TABLE 4.—*Digestibility of ration—Period I.*

Constituents and energy.	Total digested.	Digestibility.
	Grams.	*Per cent.*
Dry matter	1,801.4	61.41
Ash	89.4	44.04
Organic matter	1,712.0	62.70
Proteids	193.8	54.56
Nonproteids [a]	39.6	100.00
Crude fiber	462.2	55.37
Nitrogen-free extract	954.8	68.05
Ether extract	60.8	62.24
Nitrogen	39.36	60.36
Carbon	819.07	59.96
	Calories.	
Energy	7,767.3[b]	58.97

[a] Assumed to be wholly digestible.

[b] The calorie referred to in this bulletin is the large calorie (kilogram-calorie; often written with a capital C). A calorie is the amount of heat required to raise the temperature of 1 kilogram (2.2 pounds) of water 1 degree centigrade, or about 4 pounds of water 1 degree Fahrenheit.

Period II (February 10–19, 1904).

The following tables, corresponding to those for Period I, summarize the weights of food and excreta and the percentage digestibility of the hay, which are contained in detail in Tables II and III of the Appendix.

TABLE 5.—*Feed and excreta—Period II.*

Feed and excreta.	Fresh weight.	Dry matter.	
Hay:	*Grams.*	*Per cent.*	*Grams.*
Total in 10 days	59,000.0	85.24	50,291.5
Uneaten February 17 [a]	580.0	2.15	12.5
Uneaten February 18	27.0	23.33	6.3
Uneaten February 19	23.2	88.11	19.5
Eaten	58,369.8		50,253.3
Eaten per day	5,836.9		5,025.33
Feces:			
Total in 10 days	97,807.0	19.75	19,316.88
Spilled in calorimeter February 12	142.4	24.09	34.3
Spilled in stall February 13	51.6	38.57	19.9
Collected in calorimeter February 19	56.2	49.34	28.46
Spilled in stall February 19	4.7	27.66	1.3
Total excretion	98,061.9		19,400.84
Daily excretion	9,806.19		1,940.1

[a] Including water spilled in feed box.

TABLE 6.—*Digestibility of ration—Period II.*

Constituents and energy.	Total digested.	Digestibility.
	Grams.	*Per cent.*
Dry matter	3,085.2	61.39
Ash	146.2	40.92
Organic matter	2,939.0	62.96
Proteids	321.2	54.08
Nonproteids [a]	81.9	100.00
Crude fiber	788.2	55.97
Nitrogen-free extract	1,636.9	67.90
Ether extract	110.8	64.08
Total nitrogen	69.02	61.37
Total carbon	1,391.9	59.89
	Calories.	
Energy	13,425.7	59.51

[a] Assumed to be entirely digestible.

Period III (February 27 to March 18).

In this period the final results were as follows:

TABLE 7.—*Feed and excreta—Period III.*

Feed and excreta.	Fresh weight.	Dry matter.	
	Grams.	*Per cent.*	*Grams.*
Hay:			
Total in 10 days	48,000.0	86.48	41,510.4
Residue March 9	28.0	88.57	24.8
Residue March 9	138.5	28.51	39.6
Residue March 10	5.8	87.93	5.1
Residue March 16			8.1
Residue March 17	29.4	91.83	27.0
Residue March 17			4.2
Residue at end of period			10.2
Eaten	47,746.1		41,391.4
Eaten per day	4,774.6		4,139.14
Feces:			
Total	75,693.0	21.38	16,183.16
Spilled March 11	37.0	61.62	22.80
Spilled March 18	20.6	61.16	12.60
Adhering to duct			53.00
Total excretion	75,750.6		16,271.56
Daily excretion	7,575.06		1,627.16

TABLE 8.—*Digestibility of ration—Period III.*

Constituents and energy.	Total digested.	Digestibility.
	Grams.	*Per cent.*
Dry matter	2,511.9	60.68
Ash	104.3	36.83
Organic matter	2,407.6	62.43
Proteids	262.1	53.48
Nonproteids [a]	60.0	(100.00)
Crude fiber	642.0	53.81
Nitrogen-free extract	1,352.5	68.51
Ether extract	91.0	65.62
Total nitrogen	54.8	60.08
Total carbon	1,131.0	59.18
	Calories.	
Energy	10,869	58.64

[a] Assumed to be wholly digestible.

THE URINARY EXCRETION.

Table IV of the Appendix, based upon the weights recorded in Table I, shows the total amounts of nitrogen, carbon, and potential energy in the urine. In those cases in which some was spilled, the material was taken up as completely as possible with the aid of distilled water and the weight and nitrogen content of the washings determined. It has been assumed that their content of carbon and of energy was proportional to the nitrogen. The following table gives a summary of the average daily excretion:

TABLE 9.—*Average daily excretion in urine—Periods I, II, and III.*

Period.	Nitrogen.	Carbon.	Energy.	Energy per gram of carbon.
	Grams.	*Grams.*	*Calories.*	*Calories.*
I	50.75	112.15	1,046.40	9.33
II	69.05	168.76	1,522.25	9.02
III	60.55	141.80	1,247.16	8.79

It will be observed that the results obtained for the energy per gram of carbon in the urine tend to be rather lower than those found in Kellner's well known experiments, the average being 9.05 calories as compared with 9.6 calories found by Kellner for lean animals. On the basis of later experience, we are inclined to suspect that our estimate of the energy lost in the drying of the samples is somewhat too low. Nevertheless, the discrepancy between our figures and Kellner's is much less than in the previous year and the results have been used as reported.

GROWTH OF EPIDERMAL TISSUE.

The steer was thoroughly brushed each time immediately before entering the calorimeter and after leaving it, and the hair, dandruff, etc., in the latter case collected. To this was added the small amount brushed up from the floor of the calorimeter. In these samples determinations of nitrogen, carbon, and energy were made with the following results, which include for each period the total for the four days during which the animal was in the calorimeter.

TABLE 10.—*Weight and composition of hair, dandruff, etc.—Periods I, II, and III.*

Constituents and energy.	Period I.	Period II.	Period III.	Average.	
				Per period.	Per day.
Weight .... grams..	29.0	35.3	52.8	....	....
Dry matter .... per cent..	93.10	93.76	93.48	....	....
Weight of dry matter .... grams..	27.0	33.1	49.36	....	....
In dry matter:					
Nitrogen—					
Percentage	4.59	6.31	7.83	....	....
Weight .... grams..	1.242	2.08	3.86	2.39	0.60
Carbon—					
Percentage	36.716	40.19	42.56	....	....
Weight .... grams..	9.928	13.30	21.00	14.74	3.39
Energy—					
Per gram .... calories..	4.108	4.533	4.747	....	....
Total .... calories..	110.91	150.04	234.31	165.10	41.30

As in previous bulletins, it has been assumed that these figures represent the normal rate of production of hair, epidermis, etc., by the animal during the experiment, but not, of course, the matter and energy contained in the growth of hoofs and horns. In the succeeding computations, the averages of Table 10 have been deducted from the gain (*i. e.*, added to the loss) to determine the real gain of flesh and fat, but they have of course been included as a part of the total gain in the final computations of availability.

DETERMINATIONS OF RESPIRATORY PRODUCTS.

As was stated in the introduction, the total metabolism was determined at two different temperatures. For this purpose the animal was placed in the calorimeter on the first and second days and on the eighth and ninth days of the ten-day digestion period proper. Dur-

ing the first of these two respiration experiments the temperature of the calorimeter was kept at 19° C. and during the second at 13.5° C. In the statements which follow the dates given indicate the twenty-four hours ending at 6 p. m. on the date named.

TABLE 11.—*Dates of respiration experiments—Periods I, II, and III.*

Period.	At 19° C.	At 13.5° C.
I	January 13 and 14, 1904	January 20 and 21, 1904.
II	February 10 and 11, 1904	February 17 and 18, 1904.
III	March 9 and 10, 1904	March 16 and 17, 1904.

The respiratory products were determined during forty-eight hours continuously, the time being divided into four subperiods of twelve hours each, the apparatus used being the respiration calorimeter briefly described in Bulletin 51 of this Bureau and more fully in the Experiment Station Record, Vol. XV, p. 1037.

It is impracticable to reproduce here all the details of these determinations. For the general methods employed the reader is referred to the publications just mentioned.

CHECK TESTS.

External air.—As stated in previous bulletins, check tests are depended upon as a means of computing the amount of combustible gases contained in the air as it enters the respiration chamber. The check tests were made at intervals during the experiments here described with the following results:

TABLE 12.—*Combustible gases in external air.*

Date.	Observed volume of air.	Water weighed.	Carbon dioxid weighed.	Per 100 liters dry air at 0° C. and 760 mm.	
				Hydrogen.	Carbon.
	Liters.	*Gram.*	*Gram.*	*Milligram.*	*Milligram.*
January 7, 1904	1,090	0.0135	0.0080	0.153	0.223
January 25, 1904	1,139	.0230	.0080	.243	.208
March 1, 1904	1,090	.0170		.193	
March 21, 1904	941	.0175	.0071	.226	.224
March 21, 1904	892	.0143	.0047	.194	.157
Average				.202	.203

As before, the results are somewhat variable, but in no case are the corrections large as compared with the total amounts determined in the experiments upon the animal.

Alcohol check tests.—The accuracy of the apparatus was tested, as in previous years, by burning in it known amounts of ethyl alcohol and determining the amounts of carbon dioxid, water, and heat evolved. The results of these alcohol check tests as regards carbon dioxid and heat are given below. The results upon water have not yet proven satisfactory.

TABLE 13.—*Results of alcohol check tests.*

Date.	Duration.	Weight of alcohol.		Carbon dioxid.			Heat.		
		Hydrated.	Anhydrous.	Computed.	Observed.	Percentage observed.	Computed.	Observed.	Percentage observed.
	Hours.	*Grams.*	*Grams.*	*Grams.*	*Grams.*		*Calories.*	*Calories.*	
January 5, 1904	6	487.12	436.89	834.90	830.58	99.48	31,253	31,428	100.57
March 25, 1904	7	541.68	485.82	928.40	907.51	97.74	34,753	35,490	102.13

It will be noted that the agreement of the results in the test of January 5 is very satisfactory, while in that of March 25 a somewhat greater departure from the theoretical results occurred.

RESULTS UPON THE ANIMAL.

Tables V, VI, VII, VIII, IX, and X of the Appendix contain the results of the determinations of the respiratory products for the several periods and subperiods. These are summarized in the table following:

TABLE 14.—*Excreted in respiration.*

Period and subperiod.	Carbon as CO_2.	Carbon as CH_4.	Water.
Period I*a*:	*Grams.*	*Grams.*	*Grams.*
Subperiod 1	533.15	25.97	1,979.72
Subperiod 2	530.01	23.20	2,048.84
First day	1,063.16	49.17	4,028.56
Subperiod 3	542.45	25.40	1,925.27
Subperiod 4	552.44	27.39	1,886.38
Second day	1,094.89	52.79	3,811.65
Average	1,079.03	50.98	3,920.11
Period I*b*:			
Subperiod 1	533.80	25.36	1,242.85
Subperiod 2	539.19	23.24	1,395.35
First day	1,072.99	48.60	2,638.20
Subperiod 3	545.31	25.73	1,377.35
Subperiod 4	566.16	23.14	1,498.50
Second day	1,111.47	48.87	2,875.85
Average	1,092.23	48.74	2,757.03
Period II*a*:			
Subperiod 1	605.68	31.40	2,270.10
Subperiod 2	642.34	41.68	2,395.53
First day	1,248.02	73.08	4,665.63
Subperiod 3	642.50	38.45	2,377.88
Subperiod 4	628.97	25.43	2,358.17
Second day	1,271.47	63.88	4,736.05
Average	1,259.75	68.48	4,700.84
Period II*b*:			
Subperiod 1	615.27	19.72	1,684.21
Subperiod 2	622.32	22.05	1,649.37
First day	1,237.59	41.77	3,333.58
Subperiod 3	622.96	31.20	1,782.71
Subperiod 4	618.04	(?)	1,772.73
Second day	1,241.00	....	3,555.44
Average	1,239.30	48.64	3,444.51

TABLE 14.—*Excreted in respiration*—Continued.

Period and subperiod.	Carbon as CO_2.	Carbon as CH_4.	Water.
Period III*a*:	*Grams.*	*Grams.*	*Grams.*
Subperiod 1	587.26	[a] 28.03	2,349.54
Subperiod 2	568.68	[a] 34.07	2,283.50
First day	1,155.94	[a] 62.10	4,633.04
Subperiod 3	581.71	25.08	2,185.98
Subperiod 4	563.11	27.36	2,364.54
Second day	1,144.82	52.44	4,550.52
Average	1,150.38	....	4,591.78
Period III*b*:			
Subperiod 1	568.23	24.13	1,756.48
Subperiod 2	560.76	31.28	1,622.86
First day	1,128.99	55.41	3,379.34
Subperiod 3	568.89	31.94	1,693.32
Subperiod 4	572.29	34.35	1,851.48
Second day	1,141.18	66.29	3,544.80
Average	1,135.09	60.85	3,462.07

[a] Includes a correction for the time during which the gas supply of the combustion furnaces was cut off.

Hydrocarbon gases.—In the experiment with timothy hay in 1901–2 it was shown that the ratio of hydrogen to carbon in the combustible gases given off by the animal was almost identical with that for methane, while in the experiment of the succeeding year it was appreciably lower. The corresponding results for the present experiment were as follows:

TABLE 15.—*Composition of combustible gases.*

Period and subperiod.	Hydrogen.	Carbon.	Ratio of hydrogen to carbon.	Methane computed from carbon.
Period I*a*:	*Grams.*	*Grams.*		*Grams.*
Subperiod 1	8.03	25.97	1:3.234	34.70
Subperiod 2	7.23	23.20	1:3.209	31.00
First day	15.26	49.17	1:3.225	65.70
Subperiod 3	8.02	25.40	1:3.167	33.94
Subperiod 4	8.69	27.39	1:3.152	36.59
Second day	16.71	52.79	1:3.159	70.53
Average	15.99	50.98	1:3.188	68.11
Period I*b*:				
Subperiod 1	7.67	25.36	1:3.306	33.88
Subperiod 2	7.06	23.24	1:3.292	31.05
First day	14.73	48.60	1:3.299	64.93
Subperiod 3	8.49	25.73	1:3.031	34.38
Subperiod 4	7.15	23.14	1:3.237	30.92
Second day	15.64	48.87	1:3.125	65.30
Average	15.19	48.74	1:3.209	65.12

TABLE 15.—*Composition of combustible gases*—Continued.

Period and subperiods.	Hydrogen.	Carbon.	Ratio of hydrogen to carbon.	Methane computed from carbon.
	Grams.	*Grams.*		*Grams.*
Period II*a*:				
Subperiod 1	9.92	31.40	1:3.165	41.95
Subperiod 2	13.19	41.68	1:3.160	55.69
First day	23.11	73.08	1:3.162	97.64
Subperiod 3	12.36	38.45	1:3.111	51.37
Subperiod 4	7.91	25.43	1:3.215	33.98
Second day	20.27	63.88	1:3.151	85.35
Average	21.69	68.48	1:3.157	91.49
Period II*b*:				
Subperiod 1	6.09	19.72	1:3.238	26.35
Subperiod 2	7.43	22.05	1:2.968	29.46
First day	13.52	41.77	1:3.090	55.81
Subperiod 3	9.79	31.20	1:3.187	41.68
Subperiod 4	(?)	(?)		
Second day				
Average				
Period III*a*:				
Subperiod 1	[a] 8.89	[a] 28.03	1:3.153	37.45
Subperiod 2	[a] 10.88	[a] 34.07	1:3.131	45.52
First day	19.77	62.10	1:3.141	82.97
Subperiod 3	7.89	25.08	1:3.179	33.51
Subperiod 4	8.63	27.36	1:3.171	36.55
Second day	16.52	52.44	1:3.174	70.06
Average	18.15	57.27	1:3.155	76.52
Period III*b*:				
Subperiod 1	7.26	24.13	1:3.324	32.24
Subperiod 2	10.03	31.28	1:3.119	41.79
First day	17.29	55.41	1:3.205	74.03
Subperiod 3	10.40	31.94	1:3.071	42.67
Subperiod 4	11.06	34.35	1:3.106	45.89
Second day	21.46	66.29	1:3.089	88.56
Average	19.38	60.85	1:3.140	81.30

[a] Includes a correction.

It will be observed that in every instance the ratio of hydrogen to carbon is lower than that in methane. The average ratio for all the periods is almost exactly the same as that found in the experiments of the previous year, as reported in Bulletin 74 of this Bureau, viz, 1:3.17, which corresponds to the following composition as compared to the theoretical:

	Found.	In methane.
	Per cent.	*Per cent.*
Carbon	76.02	74.85
Hydrogen	23.98	25.15
	100.00	100.00

The presence of free hydrogen in the intestinal gases of animals has occasionally been noted, but it is difficult to see what compound richer in carbon than methane would be likely to be present. In the light of subsequent experience, we are inclined to suspect that insufficient heating of the platinized kaolin may be responsible for the deficiency of hydrogen. At any rate, pending a critical study of the method employed, we have for the present computed the excretion of methane from the amounts of carbon shown in the above table.

The results of Period II*b*, it will be noted, are exceedingly low, and none at all are reported for subperiod 4 of this period. In the subsequent computations, therefore, these results have been rejected and those obtained in Period II*a*, on the same ration, employed.

DETERMINATIONS OF HEAT.

It is impracticable to reproduce here the very voluminous records required for the determination of the heat produced, and it must suffice to indicate the general method and to summarize the main results.

As explained in Bulletin 51, the heat given off by the animal as sensible heat is removed from the apparatus by a water current, the amount thus removed being measured by the product of the amount of water passing through the absorbers and the rise in temperature during its passage through the apparatus. As noted, the temperature of the water is taken every four minutes, while the efflux of each 100 liters is noted on the records. In any portion of the experiment during which the rate of flow of water is uniform we may, without sensible error, compute the averages of the ingoing and of the outcoming temperatures and multiply the total weight of water by the difference between the two. Certain corrections are necessary, however.

First. The pipe composing our absorber being of small diameter, there is a not inconsiderable pressure upon the bulbs of the thermometers, and this pressure varies with the rate at which the water flows. Since the pressure is greater upon the ingoing than upon the outcoming thermometer, the effect is to render the observed difference in temperature too small. A correction for this effect has been worked out experimentally for the range of pressure used and is applied in the table.

Second. The friction of the water in the absorbers is itself the source of a small amount of heat, which is computed from the difference in pressure at entrance and exit and the weight of the water passing through the absorbers.

Third. As Atwater and Rosa have shown, it is essential to take account of the variation in the specific heat of water at different temperatures. We have followed their practice, and, assuming the specific heat of water at 20° C. as unity, have expressed all our

results in calories at 20°, using for this purpose the table of the specific heat of water given by those observers.[a]

Fourth. Corrections have to be made for the heat introduced into the apparatus or withdrawn from it in case the feed, drink, excreta, and vessels containing them are introduced or removed at a temperature different from that of the calorimeter. The net amount of these corrections, as appears from the table, is ordinarily small, but the single factors are sometimes not inconsiderable. This is especially the case with the feces, where considerable difficulty has been experienced in determining the true average temperature of the mass.

The results of these several computations are contained in Table XI of the Appendix. To the heat thus measured is to be added the latent heat of water vapor evaporated in and carried out of the chamber. This is computed from the results for water, assuming the latent heat of vaporization to be 0.592 calorie per gram.

The following table contains a summary of the amounts of heat measured in the calorimeter in the several periods and subperiods. By a series of accidents the results for Period II*b*, subperiods 3 and 4, were rendered valueless.

TABLE 16.—*Heat measured in calorimeter.*

	Period I*a*.	Period I*b*.	Period II*a*.	Period II*b*.	Period III*a*.	Period III*b*.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
First day:						
Subperiod 1	5,667.92	5,827.99	5,765.91	5,773.06	5,586.97	5,683.14
Subperiod 2	5,213.80	....	5,639.28	5,300.77	5,322.91	5,115.06
Total	10,881.72	....	11,405.19	11,073.83	10,909.88	10,798.20
Second day:						
Subperiod 3	5,522.33	5,956.95	5,901.96	....	5,324.48	5,345.11
Subperiod 4	5,605.56	5,739.96	5,721.91	....	5,350,96	5,561.71
Total	11,127.89	11,696.91	11,623.87	....	10,675.44	10,906.82
Average per day	11,004.8	....	11,514.53	....	10,792.66	10,852.5

RATE OF HEAT EMISSION.

As in previous experiments, the rate at which heat was emitted by the animal varied notably according as the animal was standing or lying. The following table shows the total heat emitted during the periods of standing and lying, respectively. The figures of this table relate only to the amount of heat given off by radiation and conduction and removed from the calorimeter in the water current, and do not include the heat carried off as latent heat of water vapor.

[a] U. S. Department of Agriculture, Office of Experiment Stations Bulletin 63, p. 56.

TABLE 17.—*Heat emission, standing and lying.*

Period and subperiod.	Time.	Position.	Total heat.	Heat per minute.
Period I*a*:				
Subperiod 1—	*Minutes.*		*Calories.*	*Calories.*
6.00 p. m. to 11.59 p. m.	359	Standing	2,228.63	6.2079
11.59 p. m. to 2.13 a. m.	134	Lying	639.07	4.7691
2.13 a. m. to 6.00 a. m.	227	Standing	1,628.23	7.1728
Subperiod 2—				
6.00 a. m. to 9.44 a. m.	224	Standing	1,329.16	5.9333
9.44 a. m. to 11.39 a. m.	115	Lying	471.06	4.0961
11.39 a. m. to 6.00 p. m.	381	Standing	2,200.67	5.7760
Subperiod 3—				
6.00 p. m. to 7.46 p. m.	106	Standing	652.54	6.1560
7.46 p. m. to 7.51 p. m.	5	Lying	26.50	5.3000
7.51 p. m. to 12.58 a. m.	307	Standing	1,967.26	6.4080
12.58 a. m. to 3.08 a. m.	130	Lying	581.58	4.4737
3.08 a. m. to 6.00 a. m.	172	Standing	1,154.69	6.7133
Subperiod 4—				
6.00 a. m. to 6.00 p. m.	720	Standing	4,488.83	6.2344
Period II*a*:				
Subperiod 1—				
6.00 p. m. to 2.36 a. m.	516	Standing	3,347.84	6.4880
2.36 a. m. to 5.01 a. m.	145	Lying	643.67	4.4390
5.01 a. m. to 6.00 a. m.	59	Standing	430.50	7.2796
Subperiod 2—				
6.00 a. m. to 9.41 a. m.	221	Standing	1,440.59	6.5185
9.41 a. m. to 12.46 p. m.	185	Lying	797.73	4.3120
12.46 p. m. to 2.46 p. m.	120	Standing	856.32	7.1360
2.46 p. m. to 4.29 p. m.	103	Lying	413.74	4.0169
4.29 p. m. to 6.00 p. m.	91	Standing	712.75	7.8320
Subperiod 3—				
6.00 p. m. to 8.55 p. m.	175	Standing	1,199.09	6.8519
8.55 p. m. to 10.42 p. m.	107	Lying	521.08	4.8699
10.42 p. m. to 2.05 a. m.	203	Standing	1,448.46	7.1352
2.05 a. m. to 4.33 a. m.	148	Lying	689.35	4.6577
4.33 a. m. to 6.00 a. m.	87	Standing	636.28	7.3135
Subperiod 4—				
6.00 a. m. to 8.12 a. m.	132	Standing	868.59	6.5802
8.12 a. m. to 10.36 a. m.	144	Lying	632.67	4.3935
10.36 a. m. to 1.07 p. m.	151	Standing	1,054.01	6.9802
1.07 p. m. to 2.49 p. m.	102	Lying	479.26	4.6986
2.49 p. m. to 6.00 p. m.	191	Standing	1,291.34	6.7609
Period III*a*:				
Subperiod 1—				
6.00 p. m. to 8.57 p. m.	177	Standing	1,079.26	6.0975
8.57 p. m. to 9.36 p. m.	39	Lying	160.94	4.1266
9.36 p. m. to 2.53 a. m.	317	Standing	2,005.17	6.3240
2.53 a. m. to 4.58 a. m.	125	Lying	541.65	4.3332
4.58 a. m. to 6.00 a. m.	62	Standing	409.02	6.5971
Subperiod 2—				
6.00 a. m. to 8.31 a. m.	151	Standing	939.75	6.2235
8.31 a. m. to 10.10 a. m.	99	Lying	346.29	3.4978
10.10 a. m. to 11.46 a. m.	96	Standing	649.32	6.7637
11.46 a. m. to 2.27 p. m.	161	Lying	680.80	4.2285
2.27 p. m. to 6.00 p. m.	213	Standing	1,354.92	6.3611
Subperiod 3—				
6.00 p. m. to 7.46 p. m.	106	Standing	663.16	6.2562
7.46 p. m. to 9.20 p. m.	94	Lying	427.21	4.5448
9.20 p. m. to 10.24 p. m.	64	Standing	447.00	6.9843
10.24 p. m. to 11.58 p. m.	94	Lying	426.67	4.5390
11.58 p. m. to 12.25 a. m.	27	Standing	192.46	7.1281
12.25 a. m. to 2.09 a. m.	104	Lying	489.88	4.7103
2.09 a. m. to 3.04 a. m.	55	Standing	432.65	7.8663
3.04 a. m. to 4.59 a. m.	115	Lying	563.52	4.9001
4.59 a. m. to 6.00 a. m.	61	Standing	387.83	6.3578
Subperiod 4—				
6.00 a. m. to 9.30 a. m.	210	Standing	1,295.38	6.1685
9.30 a. m. to 11.36 a. m.	126	Lying	522.45	4.1464
11.36 a. m. to 1.37 p. m.	121	Standing	757.97	6.2642
1.37 p. m. to 3.56 p. m.	139	Lying	560.45	4.0320
3.56 p. m. to 6.00 a. m.	124	Standing	814.90	6.5720
Period I*b*:				
Subperiod 1—				
6.00 p. m. to 6.00 a. m.	720	Standing	5,092.23	7.0725
Subperiod 2—				
6.00 a. m. to 6.00 p. m.	720	Standing		
Subperiod 3—				
6.00 p. m. to 6.00 a. m.	720	Standing	5,141.56	7.1411
Subperiod 4—				
6.00 a. m. to 6.00 p. m.	720	Standing	4,852.85	6.7401

TABLE 17.—*Heat emission, standing and lying*—Continued.

Period and subperiod.	Time.	Position.	Total heat.	Heat per minute.
Period II*b*:				
Subperiod 1—	*Minutes.*		*Calories.*	*Calories.*
6.00 p. m. to 1.51 a. m.	471	Standing	3,271.84	....
1.51 a. m. to 1.56 a. m.	5	Lying	32.56	6.5120
1.56 a. m. to 3.29 a. m.	93	Standing	665.08	7.1514
3.29 a. m. to 5.46 a. m.	137	Lying	690.83	5.0425
5.46 a. m. to 6.00 a. m.	14	Standing	115.70	8.2642
Subperiod 2—				
6.00 a. m. to 1.14 p. m.	434	Standing	2,648.94	6.1035
1.14 p. m. to 3.26 p. m.	132	Lying	581.85	4.4075
3.26 p. m. to 6.00 p. m.	154	Standing	1,093.56	7.1010
Subperiod 3—				
6.00 p. m. to 7.59 p. m.	119	Standing	788.46	6.6257
7.59 p. m. to 10.38 p. m.	159	Lying	861.70	5.4195
10.38 p. m. to 11.42 p. m.	64	Standing	485.74	7.5896
11.42 p. m. to 1.51 a. m.	129	Lying	739.81	5.7349
1.51 a. m. to 5.17 a. m.	206	Standing and lying.[a]	1,192.22	([a])
5.17 a. m. to 6.00 a. m.	43	Standing	333.94	7.7660
Subperiod 4—				
6.00 a. m. to 8.59 a. m.	179	Standing	1,231.48	6.8797
8.59 a. m. to 10.26 a. m.	87	Lying	454.05	5.2189
10.26 a. m. to 1.24 p. m.	178	Standing	1,202.65	6.7564
1.24 p. m. to 2.20 p. m.	56	Lying	260.11	4.6448
2.20 p. m. to 6.00 p. m.	220	Standing	1,590.73	7.2305
Period III*b*:				
Subperiod 1—				
6.00 p. m to 10.27 p. m.	267	Standing	1,815.36	6.7991
10.27 p. m. to 12.21 a. m.	114	Lying	574.49	5.0394
12.21 a. m. to 2.05 a. m.	104	Standing	751.12	7.2223
2.05 a. m. to 3.31 a. m.	86	Lying	457.29	5.3173
3.31 a. m. to 6.00 a.m.	149	Standing	1,045.05	7.0137
Subperiod 2—				
6.00 a. m. to 10.33 a. m.	273	Standing	1,587.45	5.8148
10.33 a. m. to 12.33 p. m.	120	Lying	551.84	4.5986
12.33 p. m. to 1.54 p. m.	81	Standing	497.03	6.1361
1.54 p. m. to 2.44 p. m.	50	Lying	215.99	4.3198
2.44 p. m. to 6.00 p. m.	196	Standing	1,302.02	6.6428
Subperiod 3—				
6.00 p. m. to 8.07 p. m.	127	Standing	792.55	6.2405
8.07 p. m. to 9.30 p. m.	83	Lying	394.36	4.7513
9.30 p. m. to 1.25 a. m.	235	Standing	1,612.37	6.8611
1.25 a. m. to 2.58 a. m.	93	Lying	483.30	5.1967
2.58 a. m. to 3.47 a. m.	49	Standing	312.72	6.3820
3.47 a. m. to 5.44 a. m.	117	Lying	608.25	5.1987
5.44 a. m. to 6.00 a. m.	16	Standing	139.12	8.6950
Subperiod 4—				
6.00 a. m. to 9.18 a. m.	198	Standing	1,286.64	6.4981
9.18 a. m. to 11.28 a. m.	130	Lying	574.65	4.4203
11.28 a. m. to 1.43 p. m.	135	Standing	927.79	6.8725
1.43 p. m. to 1.45 p. m.	2	Lying	2.38	1.1900
1.45 p. m. to 6.00 p. m.	255	Standing	1,674.18	6.5654

[a] The animal lay down so quietly that it was not noticed at the time. Therefore no division was made between 1.51 and 5.17 for standing and lying.

From the foregoing table have been computed the following results for the total heat emitted during the several periods in the lying and the standing positions, respectively, together with the average heat emission per minute. In making these computations the artificial division into subperiods has been disregarded.

TABLE 18.—*Average heat emission per minute.*

	Lying.	Standing.
Period I*a*:		
Minutes	384	2,496
Total heat ... calories	1,718.2	15,650.0
Heat per minute ... do	4.4747	6.2700
Ratio	1	1.4012
Period II*a*:		
Minutes	934	1,946
Total heat ... calories	4,177.5	13,285.8
Heat per minute ... do	4.4727	6.8272
Ratio	1	1.5264
Period III*a*:		
Minutes	1,096	1,784
Total heat ... calories	4,719.8	11,428.7
Heat per minute ... do	4.3064	6.4062
Ratio	1	1.4876
Period I*b* (subperiods 1, 3, and 4):		
Minutes	...	2,160
Total heat ... calories	...	15,086.64
Heat per minute ... do	...	6.9846
Period II*b* (subperiods 1 and 2 only):		
Minutes	274	1,166
Total heat ... calories	1,305.2	7,802.2
Heat per minute ... do	4.7636	6.6914
Ratio	1	1.4047
Period III*b*:		
Minutes	795	2,085
Total heat ... calories	3,862.5	13,743.4
Heat per minute ... do	4.8585	6.5915
Ratio	1	1.3566

The differences in rate of heat emission, although slightly smaller, are still quite comparable with those observed in the previous year with the same animal (Bul. 74, p. 24), while both are larger than those observed in the first year's experiments (Bul. 51, p. 37). In the results of the last two years there appears a distinct effect of the amount of feed consumed, the difference in the heat emission standing and lying tending to be greater on the heavier rations. In this year's experiments, too, the difference seems to be less in the trials at the lower temperature, although the results for periods I*b* and II*b*, as noted, are somewhat incomplete. While we should naturally ascribe these differences in heat emission chiefly to the increased muscular exertion required in standing, it would seem that there are other factors affecting it.

HEAT EMISSION AND HEAT PRODUCTION.

The figures of the preceding tables show the amounts of heat given off by the animal. The heat emitted by the animal, however, is equal to the amount of heat actually produced only when the initial and final states of the animal are the same. Consequently there may be, according to circumstances, either a storage of heat in the body or an emission of heat produced in a previous period. In this respect there are two principal sources of error—first, variations in the body temperature of the animal; second, a storage or loss of matter by the body. As regards the first of these sources of error, it has been assumed that under normal and uniform conditions the body

temperature would be substantially the same at the same hour of the day. We have not been able as yet to make systematic determinations of the body temperature of cattle as a check upon this assumption, but the rectal temperature of the animal was taken daily during the digestion periods proper of Periods I and II, except when the steer was in the calorimeter, and also during the preliminary feeding of Periods II and III and on one day during the digestion period proper of Period III. The observations were made immediately before watering, by means of a self-registering mercurial thermometer, with the following results:

TABLE 19.—*Temperature of the animal.*

Period I.		Period II.		Period III.	
Date.	Temperature.	Date.	Temperature.	Date.	Temperature.
	°C.		°C.		°C.
January 15	38.3	February 3	38.3	February 28	38.2
16	38.1	4	38.2	29	38.3
17	38.1	5	38.2	March 1	38.3
18	38.2	6	38.2	2	38.4
19	37.9	7	38.3	3	38.3
22	38.0	8	38.2	4	38.3
		9	38.1	5	38.2
Average	38.1	12	38.1	6	38.3
		13	38.2	7	38.3
		14	38.1	12	38.3
		15	38.2		
		16	38.1	Average	38.3
		19	38.3		
		Average	38.2		

In but two cases does the difference between two successive days exceed 0.1° C. With an average live weight of about 580 kilograms, assuming a specific heat of 0.8 for the body, this difference is equivalent to 46 calories.

If the animal stores up matter in its body, there must necessarily be a corresponding retention of a portion of the heat arising from body metabolism, since the matter which is stored was consumed in the food at a temperature considerably below that of the body. On the other hand, if there is a loss of matter from the body in any one of the various excreta, the temperature of this matter is reduced (either actually or by calculation) to that of the surrounding air before it leaves the calorimeter, and this heat which was previously stored up in the body is measured along with that actually produced during the experiment. The above statements are of course true whatever be the kind of matter stored up or given off; but the income and outgo of water is of especial importance in this respect, both because of its large amount and because of the high specific heat of water. Indeed, a very simple calculation serves to show that in these experiments the difference in the income and outgo of dry matter does not materially affect the computation of the balance of

energy, and that consequently only the income and outgo of water need be considered.

From the data contained in the various tables of the Appendix are compiled the following tables, showing the income and outgo of water by the animal and the corresponding gain or loss of heat on each day of the calorimeter experiments. The body temperature has been assumed to be represented by the average for the period (Table 19), while that of the calorimeter was 19.0° C. and 13.5° C. in the series *a* and *b*, respectively, except in Period III*b*, when it was 13.8° C. In the case of feces spilled in the calorimeter the water remaining in them when sampled has been divided equally between the two days.

TABLE 20.—*Approximate water balance.*

PERIOD I.

	Income.	Outgo.		Income.	Outgo.
Period I*a*:			Period I*b*:		
January 13—	*Grams.*	*Grams.*	January 20—	*Grams.*	*Grams.*
Hay	272		Hay	289	
Water	11,330		Water	3,554	
Feces		2,908	Feces		4,936
Feces spilled		37	Feces spilled		4
Urine		3,963	Urine		3,599
Water vapor		4,029	Water vapor		2,638
Balance		665	Balance	7,334	
	11,602	11,602		11,177	11,177
January 14—			January 21—		
Hay	296		Hay	270	
Water	760		Water	11,895	
Feces		4,718	Feces		5,102
Feces spilled		37	Feces spilled		4
Urine		2,984	Urine		2,583
Water vapor		3,812	Water vapor		2,876
Balance	10,495		Balance		1,600
	11,551	11,551		12,165	12,165

PERIOD II.

	Income.	Outgo.		Income.	Outgo.
Period II*a*:			Period II*b*:		
February 10—			February 17—		
Hay	536		Hay	449	
Water	11,952		Water	25,670	
Feces		9,856	Feces		7,658
Feces spilled		54	Feces spilled		14
Urine		5,209	Urine		5,242
Water vapor		4,666	Water vapor		3,334
Balance	7,297		Balance		9,871
	19,785	19,785		26,119	26,119
February 11—			February 18—		
Hay	597		Hay	504	
Water	17,470		Water	14,460	
Feces		8,696	Feces		6,921
Feces spilled		54	Feces spilled		14
Urine		5,584	Urine		5,071
Water vapor		4,736	Water vapor		3,560
Balance	1,003		Balance	602	
	19,070	19,070		15,566	15,566

TABLE 20.—*Approximate water balance*—Continued.

PERIOD III.

	Income.	Outgo.		Income.	Outgo.
Period III*a*:			Period III*b*:		
March 9—	*Grams.*	*Grams.*	March 16—	*Grams.*	*Grams.*
Hay	458		Hay	412	
Water	5,205		Water	18,100	
Uneaten residue		99	Feces		6,611
Feces		5,762	Feces spilled		4
Feces spilled		7	Urine		4,461
Urine		4,578	Water vapor		3,379
Water vapor		4,633	Balance		4,057
Balance	9,416				
	15,079	15,079		18,512	18,512
March 10—			March 17—		
Hay	451		Hay	387	
Water	16,020		Water	11,200	
Uneaten residue		53	Feces		5,779
Feces		5,100	Feces spilled		4
Feces spilled		7	Urine		4,548
Urine		4,503	Water vapor		3,545
Water vapor		4,551	Balance	2,289	
Balance		2,257			
	16,471	16,471		13,876	13,876

Upon the basis of the above figures the actual heat production has been computed, as shown in the following table, the difference between the income and outgo of water, expressed in kilograms, being multiplied by the difference between the average body temperature for the period and the temperature of the calorimeter to obtain the correction. With the exception of Period II*a*, the results for the two days of each period where such a comparison is possible show a very close agreement in the amount of heat actually produced.

TABLE 21.—*Heat production.*

Period.	Measured in calorimeter.	Correction for water balance.	Heat produced.
Period I*a*:	*Calories.*	*Calories.*	*Calories.*
First day	10,881.7	+ 12.7	10,894.4
Second day	11,127.9	−200.5	10,927.4
Average	11,004.8	− 93.9	10,910.9
Period I*b*:			
First day			
Second day	11,696.9	+ 39.4	11,736.3
Period II*a*:			
First day	11,405.2	−140.1	11,265.1
Second day	11,623.9	− 19.3	11,604.6
Average	11,514.5	− 79.7	11,434.9
Period II*b*:			
First day	11,073.8	+243.8	11,317.6
Second day			
Period III*a*:			
First day	10,909.9	−181.7	10,728.2
Second day	10,675.4	+ 43.6	10,719.0
Average	10,792.7	− 69.1	10,723.6
Period III*b*:			
First day	10,798.2	+ 99.4	10,897.6
Second day	10,906.8	− 56.1	10,850.7
Average	10,852.5	+ 21.7	10,874.2

THE BALANCE OF MATTER.

Considering the figures for epidermal tissues in Table 10 to represent the average rate of growth of hair, etc., we may subdivide the gain or loss as ordinarily computed into the growth of these tissues and the real gain or loss of the proteids and fat of the body, as has been done in the computations which follow.

THE NITROGEN AND CARBON BALANCE.

The income and outgo of nitrogen and carbon are shown in the following table. The figures for hydrogen are omitted for the reason that, as stated on page 15, the results for water were not found to be entirely satisfactory. In Period II*b*, as noted on page 19, the results on methane were apparently too low, and therefore those of Period II*a*, on the same ration, have been substituted.

TABLE 22.—*Income and outgo of nitrogen and carbon per day and head.*

Period.	Nitrogen.		Carbon.	
	Income.	Outgo.	Income.	Outgo.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Period I*a*:				
Hay	65.12		1,363.70	
Feces		25.85		546.98
Urine		50.75		112.15
Brushings		0.60		3.69
Methane				50.98
Carbon dioxid				1,079.03
Balance	12.08		429.13	
	77.20	77.20	1,792.83	1,792.83
Period I*b*:				
Hay	65.12		1,363.70	
Feces		25.85		546.98
Urine		50.75		111.61
Brushings		0.60		3.69
Methane				48.74
Carbon dioxid				1,092.38
Balance	12.08		439.70	
	77.20	77.20	1,803.40	1,803.40
Period II*a*:				
Hay	112.06		2,323.71	
Feces		43.45		931.83
Urine		69.05		168.76
Brushings		0.60		3.69
Methane				68.48
Carbon dioxid				1,259.75
Balance	1.04		108.80	
	113.10	113.10	2,432.51	2,432.51
Period II*b*:				
Hay	112.06		2,323.71	
Feces		43.45		931.83
Urine		69.05		168.76
Brushings		0.60		3.69
Methane				68.48
Carbon dioxid				1,239.30
Balance	1.04		88.35	
	113.02	113.02	2,412.06	2,412.06

TABLE 22.—*Income and outgo of nitrogen and carbon per day and head*—Continued.

Period.	Nitrogen.		Carbon.	
	Income.	Outgo.	Income.	Outgo.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Period III*a*:				
Hay	91.47		1,911.04	
Feces		36.44		780.05
Urine		60.55		141.80
Brushings		0.60		3.69
Methane				57.27
Carbon dioxid				1,150.38
Balance	6.12		222.15	
	97.59	97.59	2,133.19	2,133.19
Period III*b*:				
Hay	91.47		1,911.04	
Feces		36.44		780.05
Urine		60.55		141.80
Brushings		0.60		3.69
Methane				60.85
Carbon dioxid				1,135.09
Balance	6.12		210.44	
	97.59	97.59	2,121.48	2,121.48

GAIN OF PROTEIN AND FAT.

Excluding the brushings, the gain of protein and fat, which was of course negative in every instance, has been computed in the usual manner, using Köhler's[a] figures for the composition of the nitrogenous tissue of cattle, namely, nitrogen 16.67 per cent and carbon 52.54 per cent. In other words, body protein is equivalent to nitrogen multiplied by 6. In the computation of fat from carbon the usual factor (1.3) has been employed.

TABLE 23.—*Gain of protein and fat per day and head.*

Period.	Gain of nitrogen.	Equivalent protein (N×6).	Gain of carbon.			Equivalent gain of fat.	Computed energy of gain.		
			Total.	As protein.	As fat.		Protein.	Fat.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
I*a*	−12.08	−72.48	−429.13	−38.08	−391.05	−508.4	−413.2	−4,829.8	−5,243.0
I*b*	−12.08	−72.48	−439.70	−38.08	−401.62	−522.2	−413.2	−4,960.9	−5,374.1
II*a*	− 1.04	− 6.24	−108.80	− 3.28	−105.52	−137.2	− 35.6	−1,303.4	−1,339.0
II*b*	− 1.04	− 6.24	− 88.35	− 3.28	− 85.07	−110.6	− 35.6	−1,050.7	−1,086.3
III*a*	− 6.12	−36.72	−222.15	−19.29	−202.86	−263.7	−209.3	−2,505.2	−2,714.5
III*b*	− 6.12	−36.72	−210.44	−19.29	−191.15	−248.5	−209.3	−2,360.8	−2,570.1

THE BALANCE OF ENERGY.

In these experiments we have direct determinations of all the factors of income and outgo of energy, except the potential energy of the methane excreted and that of the tissue gained by the animal. The energy of the methane, however, may be safely computed from its amount, its heat of combustion at constant pressure being 13.344 calories per gram. The energy of the gain of tissue by the animal

[a] Zeit. f. Physiol. Chem., 31, 479.

may be estimated in the usual way from the computed amounts of protein and fat given above, using the factors 5.7 calories and 9.5 calories per gram, respectively. Having done this, we are in position to compare the income with the outgo of energy, and thus to check to a considerable extent the accuracy of our experiments. The following table contains such a comparison for each period. The difference between income and outgo, which has been entered in the table under the heading "Error," shows, of course, the extent to which our results appear to deviate from those required by the law of the conservation of energy.

TABLE 24.—*Balance of energy per day and head.*

	Period I.		Period II.		Period III.	
	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Series *a*, at 19° C.:	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Hay	13,170.7		22,557.7		18,535.1	
Feces		5,403.3		9,132.0		7,666.1
Urine		1,046.4		1,522.3		1,247.2
Brushings		41.3		41.3		41.3
Methane		908.9		1,221.0		1,021.0
Heat		10,910.9		11,434.9		10,723.6
Loss by body—						
Proteids	413.2		35.6		209.3	
Fat	4,829.8		1,303.4		2,505.2	
Error		102.9		545.2		550.4
	18,413.7	18,413.7	23,896.7	23,896.7	21,249.6	21,249.6
Series *b*, at 13.5° C.:						
Hay	13,170.7		22,557.7		18,535.1	
Feces		5,403.3		9,132.0		7,666.1
Urine		1,046.4		1,522.3		1,247.2
Brushings		41.3		41.3		41.3
Methane		868.9		[a]1,221.0		1,084.8
Heat		11,736.3		11,317.6		10,874.6
Loss by body—						
Proteids	413.2		35.6		209.3	
Fat	4,960.9		1,050.7		2,560.8	
Error	551.4			409.8		191.2
	19,096.2	19,096.2	23,644.0	23,644.0	21,105.2	21,105.2

[a] Assumed to be the same as in Period II*a*. See p. 19.

With the exception of Periods I*a* and III*b*, the agreement between the results computed from the energy balance and those computed from the balance of carbon and nitrogen is much less satisfactory than in previous years. A direct comparison of the gains or losses, however, is somewhat misleading, because all the errors of the experiments are concentrated in a single relatively small number. It seems on the whole fairer, therefore, to compare the total heat production as measured with that computed from the balance of carbon and nitrogen, as has been done in the following table:

TABLE 25.—*Heat production per day and head.*

Period.	Computed.	Observed.	Computed÷observed.
	Calories.	*Calories.*	*Per cent.*
I*a*	11,012.9	10,910.9	100.9
I*b*	11,184.9	11,736.3	95.3
II*a*	11,980.1	11,434.9	104.8
II*b*	11,727.4	11,317.6	103.6
III*a*	11,274.0	10,723.6	105.1
III*b*	11,065.8	10,874.6	101.8

The computed heat production exceeds more or less that actually observed in every instance but one. This is practically equivalent to saying either that the results for the carbon excretion are too high, or those for heat too low, or else that some nonnitrogenous body substance other than fat was being oxidized. As regards the first alternative it may be said that according to the results of our alcohol check tests in each year the tendency of the apparatus seems to be in precisely the opposite direction, viz, to give results slightly too low for carbon dioxid and too high for heat. As regards the nature of the body substances oxidized, it is of course possible that it may have consisted in part of stored-up carbohydrates (glycogen) which would evolve more CO_2 in proportion to the energy liberated than would fat. It is hardly possible, however, that this can have been the case to the large extent required to account for the observed discrepancies.

It should be noted further that the results in Periods II*b* and III*b* are somewhat uncertain, owing to various disturbances during the runs.

DISCUSSION OF RESULTS.

DIGESTIBILITY.

The results tabulated in Table III of the Appendix and summarized also under the several periods are brought together in the following table:

TABLE 26.—*Percentage digestibility.*

Constituents and energy.	Period I.	Period II.	Period III.
	Per cent.	*Per cent.*	*Per cent.*
Dry matter	61.41	61.39	60.68
Ash	44.04	40.92	36.83
Organic matter	62.70	62.96	62.43
Proteids	54.56	54.08	53.48
Nonproteids	*a* 100.00	*a* 100.00	*a* 100.00
Crude fiber	55.37	55.97	53.81
Nitrogen-free extract	68.05	67.90	68.51
Ether extract	62.24	64.08	65.62
Energy	58.97	59.51	58.64

a Assumed.

The slight differences between the several periods attest the accuracy of this part of the experiment.

METABOLIZABLE ENERGY.

The term metabolizable energy has been used by the writers to designate that portion of the total energy of the food which is capable of conversion into the kinetic form in the body. In this sense it is equivalent to energy of food minus energy of excreta or to what is often called "fuel value."

The data of the foregoing pages enable us to compute the metabolizable energy of the rations in the several periods. Before doing so, however, a certain correction is necessary in the energy of the urine. For example, in Period I the animal lost 12.08 grams of body nitrogen, corresponding to a loss of 72.48 grams of protein. According to Rubner's results, the potential energy of the urine is increased by about 7.45 calories for each gram of urinary nitrogen coming from the oxidation of body protein. In this case, then, the urine contained approximately $12.08 \times 7.45 = 90$ calories of energy not derived from the potential energy of the food but from that of body tissue. It is plain, then, that the potential energy of the urine must be diminished by this amount before it is subtracted from the gross energy of the food in order to get the true metabolizable energy of the latter. The corresponding corrections for the several periods, computed in this way, are as follows:

TABLE 27.—*Energy of urine.*

Period.	Observed.	Gain of nitrogen.	Equivalent energy.	Corrected energy of urine.
	Calories.	*Grams.*	*Calories.*	*Calories.*
I	1,046.4	−12.08	−90.0	956.4
II	1,522.3	− 1.04	− 7.8	1,514.5
III	1,247.2	− 6.12	−45.6	1,201.6

Using these corrected values the metabolizable energy of the clover hay fed is computed in the following table:

TABLE 28.—*Metabolizable energy of clover hay.*

	Period I.		Period II.		Period III.	
	Feed.	Excreta.	Feed.	Excreta.	Feed.	Excreta.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Hay	13,170.7		22,557.7		18,535.1	
Feces		5,403.3		9,132.0		7,666.1
Urine (corrected)		956.4		1,514.5		1,201.6
Methane		888.9		[a] 1,221.0		1,053.0
Metabolizable		5,922.1		10,690.2		8,614.4
	13,170.7	13,170.7	22,557.7	22,557.7	18,535.1	18,535.1

[a] Period II*a* only.

The relation of the metabolizable energy to the amount of matter in the food may be expressed in terms of calories per gram of the

total or of the digested organic matter. Computed in this way the results are as shown in the following table:

TABLE 29.—*Metabolizable energy per gram of organic matter.*

Period.	Organic matter of hay.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram of total organic matter.	Per gram of digestible organic matter.
	Grams.	*Grams.*	*Calories.*	*Calories.*	*Calories.*
I	2,730.3	1,712.0	5,922.1	2.169	3.460
II	4,668.0	2,939.0	10,690.2	2.290	3.637
III	3,856.0	2,407.6	8,614.4	2.234	3.578

The metabolizable energy of a feeding stuff may also be expressed as a percentage of the total or gross energy. Such a percentage is analogous to a digestion coefficient, so that if an average value for it were established for any particular kind of feeding stuff the amount of metabolizable energy in a given amount of it could be computed from its total energy by multiplication by this coefficient, just as the digestible dry matter or organic matter can be computed from the total amount present by the use of a digestion coefficient. The first half of the following table shows the percentage of the total energy which escaped in the several excreta or which was metabolized in the animal's body, while the second half of the table shows the same relations based upon the energy of the digested matter.

TABLE 30.—*Distribution of energy of clover hay.*

Energy.	Gross energy.				Energy of digested matter.			
	Period I.	Period II.	Period III.	Average.	Period I.	Period II.	Period III.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
In feces	41.03	40.49	41.31	40.96				
In urine	7.25	6.72	6.48	6.81	12.30	11.28	11.05	11.54
In methane	6.75	5.41	5.68	5.95	11.44	9.09	9.69	10.07
Metabolizable	44.97	47.38	46.48	46.28	76.26	79.63	79.26	78.39
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

INFLUENCE OF TEMPERATURE ON HEAT PRODUCTION.

As stated in the introduction, one of the purposes of the experiment was to observe the effect of temperature upon the total metabolism, so far as this could be done within the limited range of the apparatus. Two series of respiration experiments were made, one at 19° C. and one at 13.5° C., these being designated as series *a* and series *b*, respectively. The results have already been given in the description of the experiment, but are brought together here for more convenient comparison.

TABLE 31.—*Heat production.*

Period.	Series *a*, at 19° C.				Series *b*, at 13.5° C.			
	Given off by radiation and conduction.	Given off as latent heat of water vapor.	Correction for water balance.	Total.	Given off by radiation and conduction.	Given off as latent heat of water vapor.	Correction for water balance.	Total.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	8,684.1	2,320.7	−93.9	10,910.9	9,994.4	1,702.5	+ 39.4	11,736.3
II	8,731.6	2,782.9	−79.7	11,434.9	9,100.3	1,973.5	+243.8	11,317.6
III	8,074.3	2,718.3	−69.1	10,723.6	8,803.0	2,049.5	+ 21.7	10,874.2

In Period I*b*, as shown in Table 17, the animal stood constantly for forty-eight hours, and as would be expected the heat production appears to be abnormally high. In the other cases the difference of 5.5° C. in temperature seems to have made but a slight difference in the total heat production.

But, while this is true as regards the total amount of heat produced, the difference in temperature made a striking difference in the channel of excretion by which the body rid itself of its heat. A much less proportion of it was removed as latent heat of water vapor and correspondingly more by radiation and conduction at the lower temperature, as is shown clearly in the following table, based on the figures for heat production just given. The correction for the water balance is taken as representing heat stored temporarily in the body.

TABLE 32.—*Percentage distribution of heat produced.*

Period.	Series *a*, at 19° C.			Series *b*, at 13.5° C.		
	Given off by radiation and conduction.	Given off as latent heat of water vapor.	Stored in body.	Given off by radiation and conduction.	Given off as latent heat of water vapor.	Stored in body.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
I	79.59	21.27	−0.86	85.16	14.51	0.33
II	76.36	24.34	−0.70	80.41	17.44	2.15
III	75.29	25.35	−0.64	80.95	18.85	0.20

The relative humidity of the air does not appear in this case to have been an important factor in bringing about the marked decrease in the evaporation of water at the lower temperature. The relative humidity of the ingoing and of the outcoming air, and also the average relative humidity of the four residual samples taken at the end of each subperiod, were as follows:

TABLE 33.—*Relative humidity.*

Period.	Ingoing air.	Outcoming air.	Residual samples.
	Per cent.	*Per cent.*	*Per cent.*
I*a*	2.3	28.2	27.2
II*a*	2.4	32.1	29.7
III*a*	2.2	30.6	29.7
I*b*	4.9	29.9	28.7
II*b*	4.7	33.8	34.7
III*b*	2.3	31.2	32.3

Apparently the difference in the method of excretion of the heat was a direct effect of the lower temperature.

NET AVAILABLE ENERGY.

Both our own observations and those of others, notably those of Zuntz and his associates, have shown that a considerable portion of the metabolizable energy of the food may be consumed in those mechanical and chemical processes incident to the digestion of the food and its conversion into forms fitted to nourish the body, or may otherwise be converted into the form of heat, and so not be directly available to make good the losses of potential energy from the body caused by the vital processes. The portion of the metabolizable energy remaining after subtracting the portion thus expended represents the net contribution which the food has made to the maintenance of the stock of potential energy in the body. This portion of the energy of the food is designated as net available energy. In other words, it is energy available for maintenance.

As explained in previous bulletins, the availability of the energy of a feeding stuff is determined by a comparison of the losses of energy by the animal in periods in which different amounts of the feed in question are consumed. In this experiment three different amounts of clover hay were fed to the animal, and consequently a comparison of the three periods should give us two results regarding availability in Series *a* and two in Series *b*.

The losses of protein and fat by the animal as tabulated on preceding pages do not take account of the amounts of matter and energy contained in the brushings, which are tabulated separately. It is clear, however, that these ought to be included in a computation of availability, since a portion of the energy of the food was expended in their production. Furthermore, since the metabolizable energy of the food has been corrected in Table 27, for the gain or loss of nitrogen by the animal, the figures for the gain or loss of engery should be similarily corrected by adding to the gain (i. e., subtracting from the loss) 7.45 calories for each gram of nitrogen lost by the

animal. Indicating gain or loss by the mathematical signs + and −, the corrections and the corrected gains were as shown in the following table:

Table 34.—*Corrected gains.*

	Gain according to previous tables.	Correction for—		Corrected gain.
		Brushings.	Gain of protein.	
Computed from balance of nitrogen and carbon:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Period I*a*	−5,243.0	+41.3	+90.0	−5,111.7
Period II*a*	−1,339.0	+41.3	+ 7.8	−1,289.0
Period III*a*	−2,714.5	+41.3	+45.6	−2,627.6
Period I*b*	−5,374.1	+41.3	+90.0	−5,242.8
Period II*b*	−1,086.3	+41.3	+ 7.8	−1,037.2
Period III*b*	−2,570.1	+41.3	+45.6	−2,483.2
Computed from balance of energy:				
Period I*a*	−5,140.1	+41.3	+90.0	−5,008.8
Period II*a*	− 793.8	+41.3	+ 7.8	− 744.7
Period III*a*	−2,164.1	+41.3	+45.6	−2,077.2
Period I*b*	−5,925.5	+41.3	+90.0	−5,794.2
Period II*b*	− 676.5	+41.3	+ 7.8	− 627.4
Period III*b*	−2,378.9	+41.3	+45.6	−2,292.0

As already noted, there was no marked difference between Series *a* and Series *b* as regards heat production or loss except in Period

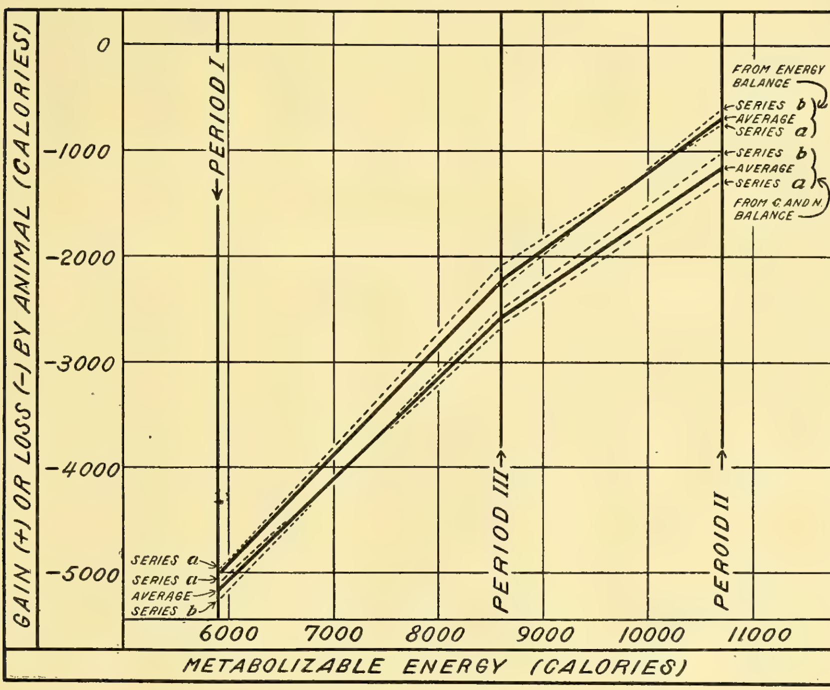

Diagram 2.—Availability of energy.

I*b*. In this period for some reason the animal refused to lie down at all. It is presumably in consequence of this fact that the observed heat production was considerably higher than in the corresponding

Period I*a*, although this is not true of the heat production as computed from the balance of nitrogen and carbon. If we arbitrarily reject Period I*b* as having been under abnormal conditions and plat the data of the remaining experiments as in previous bulletins, we have the results for the two series separately and for their average, which are shown in Diagram 2. While the losses as computed from the carbon and nitrogen balance are greater than those deduced from the energy balance, the average results of Series *a* and Series *b* are quite closely parallel.

If, on the other hand, again omitting the results for energy of Period I*b*, we average for each series separately the results as com-

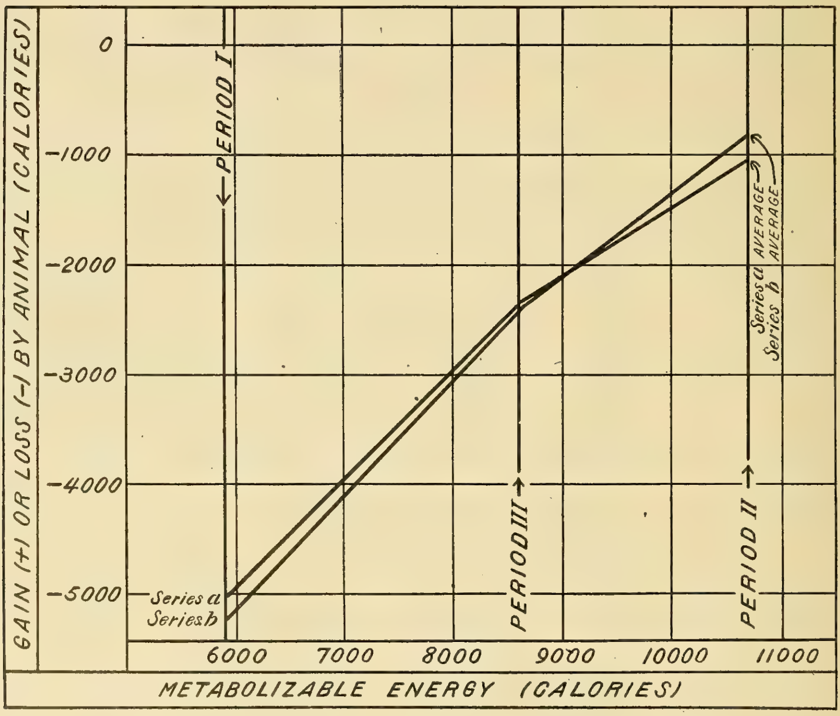

DIAGRAM 3.—Average results of carbon and nitrogen and energy balances.

puted from the carbon and nitrogen balance and those computed from the energy, we have the results shown in Diagram 3, which again expresses the fact, already pointed out, that a very slight difference was shown between the results of Series *a* and those of Series *b*.

As previously stated, the results of the calorimeter experiments I*b* and II*b* were not as satisfactory as the others. In both cases the balance of energy was obtained for twenty-four hours only, owing to various disarrangements of the apparatus, and in subperiod

4 of Period II*b* the methane determination is lacking. On the whole, therefore, we incline to attach considerably more value to the results of Series *a* than to those of Series *b*.

CORRECTIONS FOR STANDING AND LYING.

The average number of hours per day during which the animal lay down in the several periods was, as shown in Tables 17 and 18:

Period I*a*, 3 hours, 12 minutes.	Period I*b*, ———.
Period II*a*, 7 hours, 47 minutes.	Period II*b*, 2 hours, 17 minutes.
Period III*a*, 9 hours, 8 minutes.	Period III*b*, 6 hours, 38 minutes.

In view of the very marked influence of standing as compared with lying upon the metabolism of the animal, as shown in all our experiments, it is evident that the results of the several periods are not strictly comparable. Unfortunately, the data available for computing a correction are not fully sufficient, because, although the variations in the rate at which heat was given off by radiation and conduction are shown by the records of the experiment, as summarized in Tables 17 and 18, the apparatus does not permit similar determinations of the rate at which heat was carried off as latent heat of water vapor.

The best approximation which is available appears to be that outlined in Bulletin 51 of this Bureau, page 38. This consists in assuming, on the one hand, that the rate of elimination of water vapor varied at the same rate as that of the radiation of heat, and, on the other hand, that it was unaffected by the position of the animal. It would seem that these two hypotheses may be fairly regarded as representing the extremes of probable variation, and if, as appears to be the case, the results when corrected on these two hypotheses are substantially concordant, we shall be inclined to regard them as probably correct.

In place of computing the metabolism for the entire twenty-four hours either standing or lying, as was done in Bulletin 51, we have preferred in this case to compute the results, on the two hypotheses above stated, to a uniform period of seven hours passed lying down. The method of computation may be illustrated by the results of Period I*a*. In this period, as appears from Table 19, the average rate at which heat was given off by radiation and conduction and brought out of the calorimeter in the water current was:

Standing, 6.2700 calories per minute.
Lying, 4.4747 calories per minute.

If the animal had lain down for seven hours out of the twenty-four, the total heat given off through these channels would have been:

Standing 17 hours, 6.2700 calories × 1,020=6,395.4 calories.
Lying 7 hours, 4.4747 calories × 420=1,879.4 calories.

Total 24 hours .... 8,274.8 calories.

The heat actually carried off as latent heat of water vapor in this period was 2,320.7 calories, and constituted 21.09 per cent of the total heat emission. Upon the first hypothesis, then, the total heat emission would have been:

$$\frac{8,274.8}{0.7891}=10,486.4 \text{ calories.}$$

Upon the second hypothesis, that of unchanged elimination of water vapor, the total heat emission would have been:

$$8,274.8+2,320.7=10,595.5 \text{ calories.}$$

To find the actual heat production, the above figures must be corrected as in Table 21 for the results of the water balance, the correction in this period being −93.9 calories. Accordingly the heat production computed for Period I*a* on the assumption that the animal lay down for seven hours is:

On the first hypothesis, 10,392.5 calories.
On the second hypothesis, 10,501.6 calories.

Identical computations for the other periods give the results stated in the following table. In the case of Period I*b* of course no data are available for such a computation.

Table 35.—*Computed heat production—Seven hours lying.*

Period.	On the first hypothesis.	On the second hypothesis.
	Calories.	*Calories.*
I*a*	10,392.0	10,501.6
II*a*	11,580.9	11,545.5
III*a*	11,083.2	10,992.2
II*b*	10,983.6	11,043.2
III*b*	10,826.7	10,835.1

The corresponding (negative) gains by the animal—computed, of course, from the energy results, since we have no corresponding data for the carbon and nitrogen balance—would be as shown in the following table, in which the corrections for the brushings and for the gains of protein have been included in the same manner as in Table 34:

TABLE 36.—*Computed gains—Seven hours lying.*

Period.	On the first hypothesis.	On the second hypothesis.
	Calories.	*Calories.*
I*a*	—4,489.9	—4,599.5
II*a*	— 890.7	— 865.3
III*a*	—2,436.8	—2,345.8
II*b*	— 293.4	— 353.0
III*b*	—2,244.1	—2,252.5

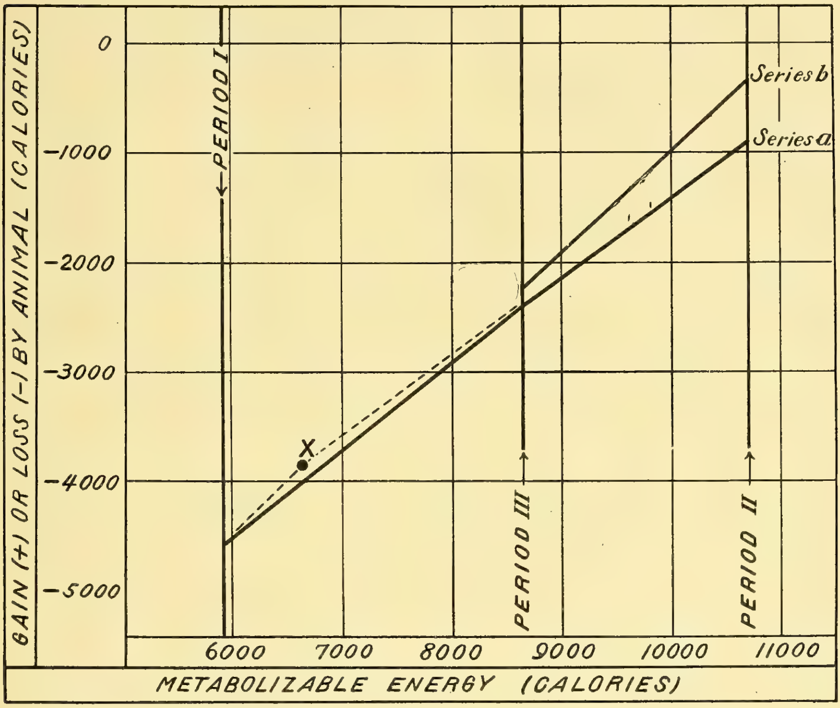

DIAGRAM 4.—Average results from energy balances computed to 17 hours' standing.

The averages of these results compared with the amounts of metabolizable energy supplied in the feed are expressed graphically in Diagram 4 and are computed numerically in the following table, which includes also the amounts of total and of digested organic matter consumed by the animal in each period.

TABLE 37.—*Availability of metabolizable energy.*

Series and period.	Organic matter.		Metabolizable energy.	On first hypothesis.		On second hypothesis.		Average.	
	Total.	Digestible.		Gain.	Availability.	Gain.	Availability.	Gain.	Availability.
Series *a*:	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Per ct.*	*Calories.*	*Per ct.*	*Calories.*	*Per ct.*
Period III	3,856.0	2,407.6	8,614.4	—2,436.8		—2,345.8		—2,391.3	
Period I	2,730.3	1,712.0	5,922.1	—4,489.9		—4,599.5		—4,544.7	
Difference	1,125.7	695.6	2,692.3	2,053.1	76.26	2,253.7	83.71	2,153.4	79.99
Period II	4,668.0	2,939.0	10,690.2	— 890.7		— 865.3		— 878.0	
Period III	3,856.0	2,407.6	8,614.4	—2,436.8		—2,345.8		—2,391.3	
Difference	812.0	531.4	2,075.8	1,546.1	74.48	1,480.5	71.32	1,513.3	72.90
Series *b*:									
Period II	4,668.0	2,939.0	10,690.2	— 293.4		— 353.0		— 323.2	
Period III	3,856.0	2,407.6	8,614.4	—2,244.1		—2,252.5		—2,248.3	
Difference	812.0	531.4	2,075.8	1,950.7	93.96	1,899.5	91.51	1,925.1	92.74

It must be admitted that the results as they stand do not appear especially satisfactory. In particular, the correction to a uniform period of lying has the effect of destroying the approximate correspondence between the results at different temperatures which was indicated by Diagrams 2 and 3. The corrected results show apparently a considerably smaller loss by the animal in Period II*b*, at the lower temperature, than in Period II*a*. This result seems unlikely, and, as already noted, both Periods I*b* and II*b* were not altogether satisfactory.

Strictly speaking, the results should be corrected also for differences in the weight of the animal. Our apparatus does not permit taking the weight of the animal during the respiration period, but the weight is taken immediately before entering and immediately after leaving the calorimeter. If we may assume that the average of the last two weights before the respiration period and the first two succeeding it represent approximately the average weight of the animal during the trial, we have the following as the live weights in the different periods:

Live weights of animal during respiration periods.

Period.	Series *a*.	Series *b*.
	Kilograms.	*Kilograms.*
I	571.1	553.7
II	586.7	576.0
III	580.1	565.8

It must be remembered, however, that these variations in weight were doubtless due to a considerable extent to variations in the amount of material contained in the digestive tract on the different rations. We can hardly suppose that the actual radiating surface of the body was materially different in the different periods, although,

on the other hand, the metabolism incident to the maintenance of the standing position would naturally be greater the greater the weight of the animal, as was indeed found to be the case. Any probable corrections for the influence of the live weight, however, are so small as to be insignificant as compared with other sources of error and are therefore not taken account of in these computations.

HEAT REQUIREMENT OF THE ANIMAL.

If we confine our attention to the results of Series *a* as being on the whole decidedly more satisfactory than those of Series *b*, we have apparently a greater average availability between Periods I and III than between Periods III and II. A similar result was noted in Bulletin 51 in the results computed for the lying position. This difference was there interpreted (page 57) as indicating an indirect utilization by the animal of the heat resulting from the digestion and assimilation of the light ration. This view assumes that at a given temperature a certain minimum amount of heat is required by the animal organism to maintain its temperature, and that if this amount of heat is not produced by the ordinary activity of the internal organs and the muscles it will be supplied by a direct combustion of food or tissue for the purpose of heat production. In the case observed in Bulletin 51 it was believed that when the animal was lying down the necessary production of heat aside from that resulting from the ingestion of food was insufficient to supply the demands of the animal. On the heavier ration a part only of the heat resulting from the work of digestion and assimilation was required, in addition to that produced by the internal work, to supply the demand for heat. As the amount of food was decreased, however, a point was reached at which all the heat produced by digestion and assimilation was required for this purpose, while with a still smaller amount of food a portion of the animal tissue had to be metabolized to supply the necessary heat. At or below this point, then, the entire metabolizable energy of the food was of use to the animal and the apparent availability became 100 per cent, represented graphically on Diagram III of Bulletin 51 by the dotted lines, making an angle of 45 degrees with the coordinates. It is of some interest to apply the same interpretation to this experiment and to compare the results obtained with those found in the previous experiment.

In the experiments of 1901–2 the average live weight of the animal in Periods A and B, the ones to be compared, was 401.8 kilograms. The computed heat production, lying, in Period A was:

On the first hypothesis	7, 920 calories.
On the second hypothesis	8, 250 calories.
Average	8, 085 calories.

This average amount we may regard as representing the minimum of heat required by the animal.

In the present experiments the average live weight for Periods I and III was 574.3 kilograms. The heat production in Period I*a*, computed to seven hours lying, was, as previously shown:

On the first hypothesis	10, 392 calories.
On the second hypothesis	10, 502 calories.
Average	10, 447 calories.

which we may regard as being the minimum required for the older and larger animal.

It seems to be fairly well established that the requirement of the animal body for heat is substantially proportional to its surface, or, what is approximately the same thing, to the two-thirds power of its volume or weight. On this hypothesis we can compute from the observed results the probable minimum requirement of an animal weighing 500 kilograms as follows:

Experiment of 1901–2.

On the first hypothesis, $7{,}920 \text{ calories} \times \left(\frac{500}{401.8}\right)^{\frac{2}{3}} = 9{,}163$ calories.

On the second hypothesis, $8{,}250 \text{ calories} \times \left(\frac{500}{401.8}\right)^{\frac{2}{3}} = 9{,}545$ calories.

Average 9, 354 calories.

Experiment of 1903–4.

On the first hypothesis, $10{,}395 \text{ calories} \times \left(\frac{500}{574.3}\right)^{\frac{2}{3}} = 9{,}478$ calories.

On the second hypothesis, $10{,}503 \text{ calories} \times \left(\frac{500}{574.3}\right)^{\frac{2}{3}} = 9{,}576$ calories.

Average 9,527 calories.

The close agreement of these figures seems to support strongly the view advanced above, namely, that on the lighter ration of Period I the animal was consuming its own tissue for heat production and that up to a point between this and the ration of Period III the food would show an apparent availability of 100 per cent. In other words, we conclude that the availability would be represented approximately by the dotted line in Diagram 4. The point at which the relation changes is indicated on the diagram at X, and could, of course, be computed numerically by the methods of analytical geometry.

If this interpretation of the results is correct, the loss of tissue in Period I*b*, at 13.5° C., should be greater than in Period I*a*, at 19° C., and, as a matter of fact, that appears to be the tendency, although the results are uncertain. On the same hypothesis the losses in Periods II and III should be the same at both temperatures. Such an

equality was observed in Period III, but not in Period II. In the latter, as already noted, the loss, computed for seven hours lying, was less at the lower than at the higher temperature.

MAINTENANCE REQUIREMENT OF THE ANIMAL.

Another method of comparing the results of the two experiments is to compute the maintenance requirement of the animal for a uniform weight of, say, 500 kilograms. The maintenance requirement may be defined as the amount of food which supplies sufficient available energy to make good the losses incident to the vital activities of the animal. Owing to the varying degree of availability of different foods, the total weight of food—or the total metabolizable energy—required will vary with the feeding stuff used. The maintenance requirement, therefore, is most logically expressed in terms of available energy, and its amount will be found graphically by producing the line representing the availability of the food until it intersects the vertical axis. The distance from the origin to this point of intersection will represent the maintenance requirement in terms of available energy, or, in other words, it will be the theoretical fasting metabolism of the animal at the given temperature. Performing the same operation arithmetically, we have, on the basis of the average results of Period II*a*, the following:

$$(10{,}690 \text{ calories} \times 0.729) + 878 \text{ calories} = 8{,}671 \text{ calories, maintenance requirement.}$$

For the experiments of 1901–2 the computation is not so simple, because the rations employed contained in each case 400 grams of linseed meal, a material whose net available energy has not yet been determined. Its utilizable energy (production value), however, compared with that of maize, as computed by the use of Kellner's factors[a], is:

100 pounds linseed meal=78,929 calories.
100 pounds maize=88,847 calories.

If we assume that the net available energy of the two materials is proportional to their utilizable energy, we may compute the net available energy of linseed meal per kilogram of dry matter from that of maize, as given in the first table on page 40 of Bulletin 74 of this Bureau, as follows:

$$2.679 \text{ calories} \times \frac{78{,}929}{88{,}847} = 2.381 \text{ calories per gram of dry matter.}$$

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[a] Pennsylvania Experiment Station Bulletin 71 (revised), page 16.

Upon this assumption the maintenance requirement of the animal in Periods A and B of the experiment of 1901–2 would be as follows:

TABLE 38.—*Computation of maintenance requirement according to experiment of 1901–2.*

	Dry matter eaten.	Net available energy per gram.	Net available energy of ration.
	Grams.	*Calories.*	*Calories.*
Period A:			
Hay	2,879.5	1.268	3,652
Linseed meal	357.8	2.381	852
Loss from body			2,578
Maintenance			7,082
Period B:			
Hay	4,018.0	1.268	5,097
Linseed meal	354.7	2.381	845
Loss from body			791
Maintenance			6,733
Average maintenance			6,908

The time spent standing in the experiment of 1901–2 was, on the average of Periods A and B, fifteen hours. This does not differ sufficiently from the seventeen hours to which the results of 1903–4 have been computed to render a correction necessary for the purposes of the present approximate comparison. The reduction of the above figures to a live weight of 500 kilograms gives the following results:

Experiment of 1903–4, 8,671 calories$\times\left(\frac{500}{583.4}\right)^{\frac{2}{3}}$=7,824 calories.

Experiment of 1901–2, 6,908 calories$\times\left(\frac{500}{401.8}\right)^{\frac{2}{3}}$=7,992 calories.

We find, then, that if we assume that the results obtained by comparing Periods II and III represent the true availability of the clover hay, and that the divergent results obtained by the comparison of Periods III and I can be explained in the manner just detailed, we obtain results which are closely concordant with those of earlier experiments both as to the minimum requirements of the animal for heat and as to the amount of available energy required for maintenance. In spite, therefore, of the somewhat unsatisfactory nature of the experiment there seems good reason to believe that the availability of the metabolizable energy of the clover hay was in the neighborhood of 73 per cent, and that the much lower figure obtained in the previous year's experiment was erroneous. The latter conclusion is further strengthened by computing in the same way from the results of that experiment the maintenance requirement of the animal in terms of available energy. A computation similar to that used above gives as a result, for the live weight of 500 kilograms, 5,907 calories. This result is so much lower than those computed from the other two experiments as to be almost certainly erroneous and indicates that for some reason the loss by the animal in Period II of the experiment in 1903 was overestimated.

DISTRIBUTION OF ENERGY.

Using the above corrected figure for the availability of clover hay, we may derive the following corrected figures for the percentage distribution of the energy of several feeds which were tabulated on pages 44 to 46 of Bulletin 74:

TABLE 39.—*Percentage distribution of total energy.*

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
In feces	48.90	40.96	40.96	9.18
In urine	3.06	6.81	5.71	3.83
In methane	3.79	5.95	6.77	9.31
Expended in digestion and assimilation	16.41	12.49	27.28	17.23
Expended in tissue formation	13.10	33.79		19.06
Stored as gain by animal	14.74		19.28	41.39
	100.00	100.00	100.00	100.00
Available for maintenance	27.84	33.79		60.45

TABLE 40.—*Percentage distribution of energy of digested matter.*

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
In urine	6.00	11.53	9.66	4.22
In methane	7.42	10.08	11.57	10.25
In digestion and assimilation	32.10	21.15	46.08	18.97
In tissue formation	25.64	57.24		20.99
Stored as gain	28.84		32.69	45.57
	100.00	100.00	100.00	100.00
Available for maintenance	54.49	27.61		66.55

The same results may also be computed in calories per unit of dry matter, using the percentages of the above tables as coefficients. The total or gross energy of the materials, taking in case of timothy hay, clover hay, and maize meal the average of the two general samples, was as follows:

TABLE 41.—*Total or gross energy of materials.*

	Per kilogram dry matter.	Per kilogram digested organic matter.
	Calories.	*Calories.*
Timothy hay	4,554	[a] 4,382
Clover hay	4,492	[b] 4,476
Maize meal	4,431	[c] 4,327
German meadow hay	4,413	4,437

[a] Preliminary period, steer No. 1. [b] Average of Periods I and II. [c] Average of Periods III and IV.

On this basis have been computed the figures of the tables following, showing the total energy per kilogram of dry matter and its distribution in accordance with the percentage figures already given.

TABLE 42.—*Energy per kilogram of total dry matter.*

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	Calories.	*Calories.*	*Calories.*	*Calories.*
Lost in feces	2,227	1,840	1,807	407
Lost in urine	139	306	252	170
Lost in methane	173	267	299	413
Expended in digestion and assimilation	747	561	1,204	763
Expended in tissue formation	597	1,518		844
Stored as gain	671		851	1,834
Total	4,554	4,492	4,413	4,431
Available for maintenance	1,268	1,518	....	2,679

TABLE 43.—*Energy per kilogram of digestible organic matter.*

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	Calories.	*Calories.*	*Calories.*	*Calories.*
Lost in urine	262	516	429	183
Lost in methane	325	451	513	443
Expended in digestion and assimilation	1,407	947	2,045	821
Expended in tissue formation	1,124	2,562		908
Stored as gain	1,264		1,450	1,972
Total	4,382	4,476	1,437	4,327
Available for maintenance	2,388	2,562	....	2,880

Taking the figures for timothy hay as unity, the relative values of these four feeding stuffs are as follows:

TABLE 44.—*Relative values.*

Feed.	Per kilogram total dry matter.		Per kilogram digestible organic matter.	
	For maintenance.	For fattening.	For maintenance.	For fattening.
Timothy hay	1.00	1.00	1.00	1.00
Clover hay	1.20	....	1.07	....
Meadow hay	....	1.27	....	1.15
Maize meal	2.11	2.73	1.21	1.56

APPENDIX.

TABLE I.—*Live weight, water drunk, and excreta of animal fed on clover hay.*

[For 24 hours ended at 6. p. m. on date given.]

Period and date.	Live weight.	Water drunk.	Feces.	Urine.[a]
Period I.				
Jan., 1904.	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*
2	619.5	0.0		
3	592.4	28.6		
4	597.0	8.0		
5	584.2	22.2		
6	586.1	0.0		
7	569.8	27.3		
8	577.8	21.0		
9	582.7	0.0		
10	570.8	0.0		
11	558.6	34.7		
12	[b] 580.8	0.0		
	[c] 577.6			
13		11.33	3,599	4,034
14	[d] 565.3	.76	5,940	3,125
15	560.5	23.9	5,425	4,803
16	565.1	24.6	5,335	11,635
17	571.2	8.5	6,042	10,002
18	562.6	9.5	5,994	10,252
19	[b] 560.7	0.0		
	[c] 557.2		5,746	6,861
20		3.554	6,172	3,724
21	[d] 550.7	11.895	6,609	2,705
22	546.2	25.8	4,075	4,650
Total			54,937	62,127
Spilled in calorimeter Jan. 14			109.1	95.85
Dung from duct Jan. 14			18.0	
Spilled in stall Jan. 16			1.2	230.96
Spilled in calorimeter Jan. 21			25.1	39.35
Spilled in stall Jan. 22			36.6	
Transition period:				
Jan. 23	552.0	19.0		
24	560.4	19.8		
25	571.0	16.4		
26	576.8	18.8		
27	582.8	15.1		
28	584.8	25.6		
29	594.9	14.0		
Period II.				
Jan., 1904.				
30	597.8	13.0		
31	597.4	40.8		
Feb., 1904.				
1	596.2	25.2		
2	596.4	5.4		
3	584.6	29.1		
4	594.9	19.5		
5	594.8	6.2		
6	584.2	22.8		
7	589.3	13.9		
8	585.0	11.3		
9	[b] 597.2			
	[c] 584.5	15.4		
10		11.952	12,165	5,446
11	[d] 587.1	17.470	10,807	5,825
12	578.1	12.1	8,725	7,468

Period and date.	Live weight.	Water drunk.	Feces.	Urine.[a]
Period II—Con.				
Feb., 1904—Con.	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*
13	567.6	22.1	10,709	7,798
14	565.1	21.8	9,324	5,977
15	573.4	14.0	10,645	8,278
16	[b] 577.6	0.0		
	[c] 572.4		8,815	7,753
17		25.67	9,711	5,484
18	[d] 579.3	14.46	8,806	5,305
19	574.8	15.60	8,100	6.452
Total			97,807	65,796
Spilled in calorimeter Feb. 11			142.4	
Spilled in stall Feb. 13			51.6	
Spilled in calorimeter Feb. 18			56.2	
Spilled in stall Feb. 19			4.7	
Transition period:				
Feb. 21	571.2	27.2		
22	581.1	20.8		
23	583.5	20.1		
24	586.3	16.9		
25	586.1	15.7		
26	587.2	22.3		
Period III.				
Feb., 1904.				
27	590.5	17.2		
28	585.7	12.9		
29	579.7	15.0		
Mar., 1904.				
1	579.0	18.5		
2	581.0	14.9		
3	579.2	11.4		
4	575.1	17.0		
5	577.8	2.3		
6	567.8	23.7		
7	578.6	2.0		
8	[b] 572.0	23.0		
	[a] 590.8			
9		5.205	7,306	4,770
10	[d] 583.6	16.020	6,504	4,697
11	573.8	1.4	8,082	5,287
12	560.2	22.2	7,768	4,735
13	569.8	7.8	7,810	4,452
14	564.2	16.1	7,710	[e] [3,097]
15	567.4		6,392	4,707
16		18.100	8,449	4,657
17	[d] 569.2	11.200	7,385	4,735
18	562.2	14.4	8,287	5,038
Total			75,693	46,175
Spilled in calorimeter Mar. 10			37.0	
Spilled in stall Mar. 14				441
Spilled in calorimeter Mar. 17			20.6	

[a] Including wash water.
[b] Taken at 7.30 a. m.
[c] Taken at 1 p. m.
[d] Taken at 6 p. m.
[e] Small loss of urine.

TABLE II.—*Composition of dry matter of feces.*

Constituents and energy.	Period I.	Period II.	Period III.	Constituents and energy.	Period I.	Period II.	Period III.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Ash	10.03	10.88	10.99	Total nitrogen	2.28	2.24	2.24
Protein (N × 6.25)	14.25	14.06	14.01	Proteid nitrogen	2.06	2.06	1.97
Crude fiber	32.90	31.95	33.86	Carbon	48.29	48.03	47.94
Nitrogen-free extract	39.56	39.91	38.21	Hydrogen	6.07	6.15	6.23
Ether extract	3.26	3.20	2.93		*Calories per gram.*	*Calories per gram.*	*Calories per gram.*
	100.00	100.00	100.00	Heat of combustion	4,770.4	4,707.0	4,711.4

TABLE III.—*Digestibility of rations.*

	Dry matter.	Ash.	Organic matter.	Proteids.	Non-proteids.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Nitrogen.	Carbon.	Energy.
Period I.	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Cals.*
Hay	2,933.3	203.0	2,730.3	355.2	39.6	834.8	1,403.0	97.7	65.2	1,366.1	13,170.7
Feces	1,131.9	113.6	1,018.3	161.4	......	372.6	448.2	36.9	25.9	547.0	5,403.3
Digested	1,801.4	89.4	1,712.0	193.8	39.6	462.2	954.8	60.8	39.3	819.1	7,767.4
Coefficient, p.ct.	61.41	44.04	62.70	54.56	100.00	55.37	68.05	62.24	60.36	59.96	58.97
Period II.											
Hay	5,025.3	357.3	4,668.0	594.0	81.9	1,408.1	2,411.1	172.9	112.5	2,323.7	22,557.7
Feces	1,940.1	211.1	1,729.0	272.8	......	619.9	774.2	62.1	43.5	931.8	9,132.0
Digested	3,085.2	146.2	2,939.0	321.2	81.9	788.2	1,636.9	110.8	69.0	1,391.9	13,425.7
Coefficient, p.ct.	61.39	40.92	62.96	54.08	100.00	55.97	67.90	64.08	61.37	59.89	59.51
Period III.											
Hay	4,139.1	283.1	3,856.0	490.1	60.0	1,193.0	1,974.2	138.7	91.2	1,911.0	18,535.1
Feces	1,627.2	178.8	1,448.4	228.0	......	551.0	621.7	47.7	36.4	980.0	7,666.1
Digested	2,511.9	104.3	2,407.6	262.1	60.0	642.0	1,352.5	91.0	54.8	1,131.0	10,869.0
Coefficient, p.ct.	60.68	36.83	62.43	53.48	100.00	53.81	68.51	65.62	60.08	59.18	58.64

TABLE IV.—*Results on urine (inclusive of wash water).*

Period.	Weight.	Average specific gravity.	Total nitrogen.		Total carbon.		Energy.	
							Per kilogram.	Total.
Period I.	*Grams.*		*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Calories.*	*Calories.*
Total collected	62,157	....	0.813	507.53	1.797	1,121.48	....	....
Daily average (10 days)	6,215.7	1.0379	....	50.75	....	112.15	167.6	1,046.40
Period II.								
Total collected	65,796	....	1.050	690.5	2.566	1,687.6	....	....
Daily average (10 days)	6,579.6	1.0411	....	69.05	....	168.76	231.4	1,522.25
Period III.								
Total collected	46,616	....	1.299	605.5	3.040	1,418.0	....	....
Daily average (10 days)	4,661.6	1.0432	....	60.55	....	141.80	267.5	1,247.16

TABLE V.—*Residual air.*

Period.	Aspirator reading.	Barometer.[a]	Temperature.	Weight.		Corresponding volume at 0° and 760 mm.		Total volume of sample reduced.		Volume of moist air in chamber reduced.	Total in chamber.	
				Water.	Carbon dioxid.	Water.	Carbon dioxid.	Dry.	As sampled.		Water.	Carbon dioxid.
Period Ia.	*Liters*	*Mm.*	*° C.*	*Gms.*	*Gms.*	*Liters*	*Liters*	*Liters*	*Liters*	*Liters*	*Gms.*	*Gms.*
At end of preliminary run...	25	713.44	15.6	0.1104	0.1064	0.14	0.05	22.24	22.38	10,753	53.04	51.12
At end of subperiod 1........	25	710.29	19.0	.1003	.1066	.12	.05	21.89	22.01	10,759	49.03	52.11
At end of subperiod 2........	25	701.80	20.2	.1088	.1020	.14	.05	21.55	21.69	10,646	53.40	50.07
At end of subperiod 3........	25	701.56	19.6	.1034	.0999	.13	.05	21.58	21.71	10,636	50.66	48.94
At end of subperiod 4........	25	705.37	19.1	.1041	.1122	.13	.06	21.75	21.88	10,687	50.84	54.80
Period IIa.												
At end of preliminary run...	25	723.33	17.0	.1129	.1211	.14	.06	22.46	22.60	10,917	54.54	58.50
At end of subperiod 1........	25	724.72	17.6	.1218	.1103	.15	.06	22.46	22.61	10,941	58.94	53.37
At end of subperiod 2........	25	724.17	18.2	.1169	.1198	.15	.06	22.39	22.54	10,944	56.76	58.17
At end of subperiod 3........	25	723.97	18.4	.1156	.1096	.14	.06	22.37	22.51	10,945	56.21	53.29
At end of subperiod 4........	25	720.98	19.2	.1159	.1142	.14	.06	22.22	22.36	10,911	56.55	55.72
Period IIIa.												
At end of preliminary run...	25	706.43	18.8	.1093	.1046	.14	.05	21.79	21.93	10,693	53.30	51.00
At end of subperiod 1........	25	710.71	16.8	.1114	.1010	.14	.05	22.07	22.21	10,726	53.80	48.78
At end of subperiod 2........	25	713.05	17.3	.1169	.1111	.14	.06	22.12	22.26	10,766	56.54	53.73
At end of subperiod 3........	25	717.18	17.2	.1189	.1010	.15	.05	22.27	22.42	10,825	57.41	48.76
At end of subperiod 4........	25	712.37	18.9	.1173	.1090	.15	.05	21.97	22.12	10,778	57.16	53.11
Period Ib.												
At end of preliminary run...	25	731.04	13.2	.0832	.1106	.10	.06	23.00	23.10	11,254	40.53	53.88
At end of subperiod 1........	25	724.46	16.0	.0657	.1066	.08	.05	22.56	22.64	11,198	32.50	52.73
At end of subperiod 2........	25	719.80	15.6	.0900	.1087	.11	.05	22.45	22.56	11,068	44.16	53.33
At end of subperiod 3........	25	717.81	14.6	.0867	.1117	.11	.06	22.47	22.58	11,028	42.34	54.55
At end of subperiod 4........	25	713.40	16.0	.0856	.1088	.11	.05	22.22	22.33	10,979	42.09	53.49
Period IIb.												
At end of preliminary run...	25	720.25	14.1	.0715	.1031	.09	.05	22.58	22.67	11,068	34.91	50.34
At end of subperiod 1........	25	720.49	18.0	.1165	.1121	.14	.06	22.29	22.43	10,959	56.92	54.77
At end of subperiod 2........	25	724.84	15.6	.0921	.1152	.11	.06	22.61	22.72	11,143	45.17	56.50
At end of subperiod 3........	25	725.20	16.2	.0961	.1171	.12	.06	22.58	22.70	11,142	47.17	57.48
At end of subperiod 4........	25	722.80	16.8	.0933	.1130	.12	.06	22.46	22.58	11,128	45.98	55.69
Period IIIb.												
At end of preliminary run...	25	712.67	15.7	.0830	.1043	.10	.05	22.22	22.32	10,954	40.73	51.19
At end of subperiod 1........	25	715.66	19.1	.0771	.0980	.10	.05	22.05	22.15	11,051	38.46	48.90
At end of subperiod 2........	25	721.80	16.6	.0879	.1047	.11	.05	22.43	22.54	11,084	43.22	51.49
At end of subperiod 3........	25	726.14	15.6	.1054	.1065	.13	.05	22.65	22.78	11,143	51.56	52.10
At end of subperiod 4........	25	719.79	17.5	.0981	.1156	.12	.06	22.31	22.43	11,077	48.45	57.09

[a] Corrected for tension of aqueous vapor. The air in the aspirator is assumed to be saturated.

TABLE VI.—*Ventilation.*

Period.	Volume at meter pump.	Average barometer.	Average tension of aqueous vapor.	Average temperature.	Reduced volume at meter pump, dry.	Sample of residual air.	Methane produced.	Volume of entering air, dry.
Period Ia.	*Liters.*	*Mm.*	*Mm.*	° *C.*	*Liters.*	*Liters.*	*Liters.*	*Liters.*
Subperiod 1......	454,412	726.6	1.66	16.8	408,344.4	21.89	48.61	408,317.6
Subperiod 2......	462,239	722.0	1.20	18.0	411,279.9	21.55	43.44	411,258.0
Subperiod 3......	463,428	718.8	1.09	18.0	410,587.3	21.58	50.78	410,588.1
Subperiod 4......	463,923	719.9	1.13	18.2	411,347.4	21.75	51.26	411,317.9
Period IIa.								
Subperiod 1......	471,503	739.0	1.75	15.3	433,076.6	22.46	58.79	433,040.3
Subperiod 2......	488,990	740.9	1.50	16.3	448,937.8	22.39	78.03	448,882.2
Subperiod 3......	488,247	739.9	1.48	15.5	448.887.4	22.37	71.99	448,837.7
Subperiod 4......	487,949	739.0	1.60	17.8	444,520.9	22.22	47.60	444,495.6
Period IIIa.								
Subperiod 1......	488,147	724.3	1.69	16.6	437,473.2	22.07	52.46	437,442.8
Subperiod 2......	493,993	727.3	2.37	16.6	444,206.9	22.12	63.77	444,165.2
Subperiod 3......	495,677	730.6	2.04	15.3	450,045.0	22.27	46.95	450,020.3
Subperiod 4......	498,936	731.8	1.68	15.5	453,543.0	21.97	51.23	453,513.8
Period Ib.								
Subperiod 1......	453,669	740.4	1.31	12.4	422,112.0	22.56	47.47	422,087.0
Subperiod 2......	459,415	735.4	1.02	14.0	422,288.6	22.45	43.50	422.267.6
Subperiod 3......	453,719	731.7	1.10	14.3	414,500.4	22.47	48.18	414,474.7
Subperiod 4......	454,164	728.4	1.00	14.6	412,627.8	22.22	43.33	412,606.7
Period IIb.								
Subperiod 1......	487,850	734.5	1.50	14.2	447,273.2	22.29	36.92	447,258.6
Subperiod 2......	491,863	737.2	1.00	15.1	451,481.2	22.61	41.28	451,462.0
Subperiod 3......	487,751	738.6	1.10	13.6	450,851.2	22.58	58.41	450,815.3
Subperiod 4......	492,110	737.5	.98	14.1	453,460.5	22.46	26.84	453,456.1
Period IIIb.								
Subperiod 1......	498,006	729.1	1.77	15.1	451,671.8	22.05	45.17	451,648.6
Subperiod 2......	498,848	734.4	2.35	15.4	454,774.7	22.43	58.57	454,738.6
Subperiod 3......	493,745	738.0	1.60	14.1	454,942.9	22.65	59.79	454,905.8
Subperiod 4......	496,321	737.9	1.45	15.4	455,316.7	22.31	64.31	455,274.7

TABLE VII.—*Ingoing air.*

Period.	Aspirator reading.	Barometer.[a]	Temperature.	Reduced aspirator reading, dry.	Volume of carbon dioxid.	Total volume of sample reduced and dry.	Ratio of sample to total ventilation.	Water. In sample.	Water. In total ventilation.	Carbon dioxid. In sample.	Carbon dioxid. In total ventilation.
Period Ia.	*Liters*	*Mm.*	*° C.*	*Liters.*	*Liters*	*Liters.*	*1:*	*Gram.*	*Grams.*	*Gram.*	*Gms.*
Subperiod 1	200	711.1	20.4	174.12	0.05	174.17	2,344.4	0.0927	217.3	0.1064	294.4
Subperiod 2	200	700.2	21.6	170.76	.05	170.81	2,407.7	.0622	149.8	.1092	262.9
Subperiod 3	200	703.0	21.2	172.25	.05	172.30	2,382.8	.0646	153.9	.1061	252.8
Subperiod 4	200	706.5	20.6	172.87	.05	172.92	2,378.7	.0664	157.9	.1049	249.5
Period IIa.											
Subperiod 1	200	725.7	19.2	178.43	.05	178.48	2,426.3	.1244	301.8	.1062	257.7
Subperiod 2	200	724.7	19.6	177.95	.05	178.00	2,521.8	.0623	157.1	.1047	264.0
Subperiod 3	200	726.5	20.0	178.14	.05	178.19	2,518.9	.0644	162.2	.1013	255.2
Subperiod 4	200	722.7	20.8	176.72	.05	176.77	2,514.5	.0547	137.6	.1053	264.8
Period IIIa.											
Subperiod 1	200	710.2	18.8	174.84	.05	174.89	2,501.3	.0761	190.4	.1053	263.4
Subperiod 2	200	712.2	18.6	175.47	.05	175.52	2,530.6	.0679	171.8	.1040	263.2
Subperiod 3	200	718.6	18.2	177.28	.05	177.33	2,537.8	.0679	172.3	.1043	264.7
Subperiod 4	200	714.4	20.4	174.92	.05	174.97	2,592.0	.0668	173.1	.1074	278.4
Period Ib.											
Subperiod 1	200	726.2	17.4	179.66	.06	179.72	2,348.6	.1188	279.0	.1143	268.4
Subperiod 2	200	720.3	17.0	178.44	.06	178.50	2,365.6	.1653	391.0	.1176	278.2
Subperiod 3	200	718.1	15.4	178.89	.06	178.95	2,316.2	.1146	265.4	.1133	262.4
Subperiod 4	200	714.4	17.2	176.86	.05	176.91	2,332.3	.0582	135.7	.1057	246.5
Period IIb.											
Subperiod 1	200	722.3	19.4	177.47	.05	177.52	2.519.5	.1217	306.6	.1030	259.5
Subperiod 2	200	724.5	16.4	179.85	.05	179.90	2,509.5	.2228	559.1	.1040	261.0
Subperiod 3	200	726.6	18.0	179.39	.05	179.44	2.512.4	.0590	148.2	.1069	268.6
Subperiod 4	200	724.3	17.8	178.95	.05	179.00	2,533.3	.0365	92.46	.1072	271.6
Period IIIb.											
Subperiod 1	200	718.7	20.4	175.99	.05	176.04	2,565.6	.0562	144.2	.1040	266.8
Subperiod 2	200	722.0	16.6	179.10	.05	179.15	2,538.3	.0558	141.6	.1060	269.1
Subperiod 3	200	726.8	17.4	179.80	.05	179.85	2,529.4	.0527	133.3	.1065	269.4
Subperiod 4	200	720.8	19.0	177.34	.05	177.39	2,566.5	.0551	141.4	.1092	280.3

[a] Corrected for tension of aqueous vapor. The air in the aspirator is assumed to be saturated.

TABLE VIII.—*Carbon dioxid.*

Period.	Carbon dioxid in samples (corrected).[a] Pan No. 1.	Pan No. 2.	Total, Nos. 1 and 2×100 and corrected.[b]	In sample of residual air.	Correction for residual air.	Total CO_2 in outcoming air.	Total CO_2 in ingoing air.	CO_2 added in chamber.	Equivalent carbon.
Period Ia.	*Grams.*	*Grams.*	*Grams.*	*Gram.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Subperiod 1	10.9642	11.0337	2,203.4	0.1	+1.0	2,204.5	249.4	1,955.1	533.2
Subperiod 2	11.0263	11.0203	2,208.3	.1	−2.0	2,206.4	262.8	1,943.6	530.0
Subperiod 3	11.1844	11.2091	2,243.0	.1	−1.1	2,242.0	252.8	1,989.2	542.5
Subperiod 4	11.3608	11.2954	2,268.4	.1	+5.9	2,275.3	249.5	2,025.8	552.4
Period IIa.									
Subperiod 1	12.3888	12.4076	2,483.7	.1	−5.1	2,478.7	257.7	2,221.0	605.7
Subperiod 2	13.0521	13.0508	2,614.6	.1	+4.8	2,619.5	264.0	2,355.5	642.3
Subperiod 3	13.0874	13.0295	2,616.0	.1	−4.9	2,611.2	255.2	2,356.1	642.5
Subperiod 4	12.7990	12.8457	2,568.7	.1	+2.4	2,571.2	264.8	2,306.5	629.0
Period IIIa.									
Subperiod 1	12.1124	12.0378	2,419.0	.1	−2.2	2,416.9	263.4	2,153.5	587.3
Subperiod 2	11.6727	11.7236	2,343.5	.1	+5.0	2,348.6	263.2	2,085.4	568.7
Subperiod 3	11.9952	11.9922	2,402.7	.1	−5.0	2,397.8	264.7	2,133.1	581.7
Subperiod 4	11.6808	11.6693	2,338.9	.1	+4.4	2,343.3	278.4	2,064.9	563.1
Period Ib.									
Subperiod 1	11.1265	11.1061	2,226.9	.1	−1.2	2,225.9	268.4	1,957.5	533.8
Subperiod 2	11.3118	11.1981	2,254.7	.1	+ .6	2,255.4	278.2	1,977.2	539.2
Subperiod 3	11.2516	11.3297	2,261.9	.1	+1.2	2,263.2	262.4	2,000.8	[c] 545.3
Subperiod 4	11.5985	11.5990	2,323.6	.1	−1.1	2.322.6	246.5	2,076.1	566.2
Period IIb.									
Subperiod 1	12.5948	12.4758	2,511.2	.1	+4.4	2,515.7	259.5	2,256.2	615.3
Subperiod 2	12.7031	12.6671	2,541.2	.1	+1.7	2,543.1	261.0	2,282.1	622.3
Subperiod 3	12.7993	12.6885	2,553.0	.1	+1.0	2,554.1	268.6	2,285.5	[c] 623.0
Subperiod 4	12.6649	12.6897	2,539.6	.1	−1.8	2,538.0	271.6	2,266.4	618.0
Period IIIb.									
Subperiod 1	11.7520	11.7364	2,352.7	.1	−2.3	2,350.5	266.8	2,083.7	568.2
Subperiod 2	11.5499	11.6389	2,322.7	.1	+2.6	2,325.4	269.1	2,056.3	560.8
Subperiod 3	11.8184	11.6908	2,354.8	.1	+ .6	2,355.5	269.4	2,086.1	568.9
Subperiod 4	11.8825	11.8158	2,373.7	.1	+5.0	2,378.9	280.3	2,098.6	572.3

[a] For number of pump strokes.
[b] For a slight leakage from the pans, amounting to about 0.165 per cent of the total volume.
[c] Correction applied for man entering chamber, −0.3 gram carbon.

Table IX.—*Water.*

Period.	Water in samples (corrected).[a]		Total, Nos. 1 and 2×100 (corrected).[b]	In cans.	On absorbers.	In sample of residual air.	Correction for residual air.	Correction of hygrometer.	Total H_2O in outcoming air + absorbers.	Total H_2O in ingoing air.	Water added in chamber.	Equivalent hydrogen.
	Pan No. 1.	Pan No. 2.										
Period Ia.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gm.*	*Gm.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Subperiod 1	3.7923	3.8547	766.0	1,440.0	0.0	0.1	− 4.0	−5.0	2,197.0	217.3	1,979.7	220.0
Subperiod 2	2.8452	2.8766	573.1	1,626.0	.0	.1	+ 4.4	−5.0	2,198.6	149.8	2,048.8	227.7
Subperiod 3	2.5353	2.5547	509.8	1,577.0	.0	.1	+ 2.7	−5.0	2,079.2	153.9	1,925.3	213.9
Subperiod 4	2.6640	2.6476	532.0	1,517.0	.0	.1	+ .2	−5.0	2,044.3	157.9	1,886.4	209.6
Period IIa.												
Subperiod 1	4.1329	4.1775	832.4	1,740.0	.0	.1	+ 4.4	−5.0	2,571.9	301.8	2,270.1	252.2
Subperiod 2	3.6795	3.6654	735.7	1,824.0	.0	.1	− 2.2	−5.0	2,552.6	157.1	2,395.5	266.2
Subperiod 3	3.6035	3.6398	725.5	1,820.0	.0	.1	− .6	−5.0	2,540.1	162.2	2,377.9	264.2
Subperiod 4	4.0213	4.0380	807.3	1,693.0	.0	.1	+ .3	−5.0	2,495.7	137.5	2,358.2	262.0
Period IIIa.												
Subperiod 1	6.3729	6.4288	1,282.3	1,262.0	.0	.1	+ .5	−5.0	2,539.9	190.4	2,349.5	261.1
Subperiod 2	5.9328	5.9024	1,185.5	1,272.0	.0	.1	+ 2.7	−5.0	2,455.3	171.8	2,283.5	253.7
Subperiod 3	5.1046	5.1016	1,022.3	1,340.0	.0	.1	+ .9	−5.0	2,358.3	172.3	2,186.0	242.9
Subperiod 4	4.2235	4.2406	847.8	1,695.0	.0	.1	− .3	−5.0	2,537.7	173.1	2,364.5	262.7
Period Ib.												
Subperiod 1	3.0157	3.0425	606.8	928.0	.0	.1	− 8.0	−5.0	1,521.9	279.0	1,242.9	138.1
Subperiod 2	2.3775	2.3810	476.6	1,303.0	.0	.1	+11.7	−5.0	1,786.4	391.0	1,395.4	155.0
Subperiod 3	2.5541	2.5526	511.5	1,138.0	.0	.1	− 1.8	−5.0	1,642.8	265.4	1,377.4	[c]153.0
Subperiod 4	2.3299	2.3264	466.4	1,173.0	.0	.1	− .3	−5.0	1,634.2	135.7	1,498.5	166.5
Period IIb.												
Subperiod 1	3.6076	3.6374	725.7	1,248.0	.0	.1	+22.0	−5.0	1,990.8	306.6	1,684.2	187.1
Subperiod 2	2.4445	2.4589	491.2	1,734.0	.0	.1	−11.8	−5.0	2,208.5	559.1	1,649.4	183.3
Subperiod 3	2.7217	2.7077	543.8	1,390.0	.0	.1	+ 2.0	−5.0	1,930.9	148.2	1,782.7	[c]198.0
Subperiod 4	2.4214	2.4335	486.3	1,385.0	.0	.1	− 1.2	−5.0	1,865.2	92.5	1,772.7	197.0
Period IIIb.												
Subperiod 1	4.4379	4.4660	891.9	1,016.0	.0	.1	− 2.3	−5.0	1,900.7	144.2	1,756.5	195.2
Subperiod 2	3.6533	3.6412	730.7	1,034.0	.0	.1	+ 4.8	−5.0	1,764.5	141.6	1,622.9	180.3
Subperiod 3	3.9753	3.9933	798.2	1,025.0	.0	.1	+ 8.3	−5.0	1,826.6	133.3	1,693.3	188.2
Subperiod 4	3.6247	3.6324	726.9	1,274.0	.0	.1	− 3.1	−5.0	1,992.9	141.4	1,851.5	205.7

[a] For number of pump strokes.
[b] For slight leakage from pans, see previous table.
[c] Correction applied for man entering chamber −0.05 gram hydrogen.

TABLE X.—*Carbon and hydrogen in combustible gases.*

Period.	Total CO_2 weighed $\times 200$ (corrected).[a]	Correction for ingoing air.	Carbon as hydrocarbon.	Total H_2O weighed $\times 200$ (corrected).[a]	Correction for ingoing air.	Hydrogen as hydrocarbon.	Methane, $CO_2 \times .3643$.
Period Ia.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Subperiod 1	98.26	−3.04	25.97	79.69	−7.42	8.03	35.80
Subperiod 2	88.15	−3.06	23.20	72.54	−7.47	7.23	32.11
Subperiod 3	96.20	−3.05	25.40	79.65	−7.46	8.02	35.05
Subperiod 4	103.47	−3.06	27.39	85.72	−7.47	8.69	37.69
Period IIa.							
Subperiod 1	118.37	−3.22	31.40	97.12	−7.86	9.92	43.12
Subperiod 2	156.18	−3.34	41.68	126.83	−8.15	13.19	56.90
Subperiod 3	144.34	−3.34	38.45	119.36	−8.15	12.36	52.58
Subperiod 4	96.54	−3.30	25.43	79.23	−8.07	7.91	35.17
Period IIIa.							
Subperiod 1	106.02	−3.25	28.03	87.95	−7.94	8.89	38.62
Subperiod 2	128.22	−3.30	34.07	106.00	−8.07	10.88	46.71
Subperiod 3	95.32	−3.35	25.08	79.17	−8.17	7.89	34.73
Subperiod 4	103.71	−3.37	27.36	85.92	−8.24	8.63	37.78
Period Ib.							
Subperiod 1	96.12	−3.14	25.36	76.67	−7.67	7.67	35.02
Subperiod 2	88.35	−3.14	23.24	71.18	−7.67	7.06	32.19
Subperiod 3	97.74	−3.37	25.73	84.68	−8.24	8.49	35.61
Subperiod 4	87.94	−3.07	23.14	71.86	−7.49	7.15	32.04
Period IIb.							
Subperiod 1	75.64	−3.33	19.72	62.94	−8.12	6.09	27.56
Subperiod 2	84.22	−3.36	22.05	75.10	−8.20	7.43	30.68
Subperiod 3	117.75	−3.35	31.20	96.36	−8.19	9.80	42.90
Subperiod 4	.....	.....	.....	.....	.....	.....	.....
Period IIIb.							
Subperiod 1	91.83	−3.36	24.13	73.50	−8.20	7.26	33.45
Subperiod 2	118.09	−3.38	31.28	98.54	−8.26	10.03	43.02
Subperiod 3	120.50	−3.38	31.94	101.83	−8.26	10.40	43.90
Subperiod 4	129.35	−3.39	34.35	107.78	−8.27	11.06	47.12

[a] For slight leakage from pans, see previous table.

TABLE XI.—*Heat measurements.*

Period.	Relative rate of flow.	Average temperature of water current. Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.	Total water.	Average specific heat of water.	Heat produced in absorbers. Difference of pressure.	Equivalent heat.	Total heat, calories at 20.°
PERIOD I*a*.											
Subperiod 1.		°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*		*Cm.*	*Cal.*	
6 p. m. to 6.51 p. m.	29.0	7.5062	12.5308	5.0246	+0.0008	5.0254	59.00	1.0030	0.40	0.01	297.38
6.51 p. m. to 11.59 p. m.	30.0	6.8605	10.7945	3.9340	.0010	3.9350	490.00	1.0035	.50	.08	1,934.82
11.59 p. m. to 12.40 a. m.	28.0	6.6220	12.0500	5.4280	.0006	5.4286	35.00	1.0033	.30	......	190.64
12.40 a. m. to 1.08 a. m.	27.0	6.8814	13.5243	6.6429	.0004	6.6433	16.00	1.0030	.20	......	106.61
1.08 a. m. to 2.13 a. m.	28.0	6.0665	12.2594	6.1929	.0006	6.1935	55.00	1.0035	.30	.01	341.82
2.13 a. m. to 6 a. m.	30.0	5.0205	9.6850	4.6645	.0010	4.6655	349.50	1.0044	.50	.06	1,637.71
											4,508.98
Latent heat of water vapor											1,171.99
Correction for feed, water, excreta, and vessels											−13.05
Total heat											5,667.92
Subperiod 2.											
6 a. m. to 8.17 a. m.	30.0	5.2237	9.3171	4.0934	.0010	4.0944	209.00	1.0044	.50	.03	859.46
8.17 a. m. to 9.06 a. m.	29.0	5.4425	10.1983	4.7558	.0008	4.7566	60.00	1.0041	.40	.01	286.55
9.06 a. m. to 10.14 a. m.	28.0	5.7324	11.4200	5.6876	.0006	5.6882	60.00	1.0038	.30	.01	342.58
10.14 a. m. to 11.39 a. m.	27.0	6.4975	13.6640	7.1665	.0004	7.1669	44.50	1.0031	.20	......	319.92
11.39 a. m. to 6 p. m.	28.0	6.2513	12.8185	6.5672	.0006	6.5678	331.50	1.0033	.30	.03	2,184.38
											3,992.89
Latent heat of water vapor											1,212.91
Correction for feed, water, excreta, and vessels											+8.00
Total heat											5,213.80
Subperiod 3.											
6 p. m. to 6.42 p. m.	28.0	6.3282	12.9191	6.5909	.0006	6.5915	38.00	1.0032	.30	......	251.28
6.42 p. m. to 7.46 p. m.	29.0	6.0525	11.4269	5.3744	.0008	5.3752	76.50	1.0036	.40	.01	412.67
7.46 p. m. to 7.51 p. m.	28.0	6.1400	11.4200	5.2800	.0006	5.2806	5.00	1.0036	.30	......	26.50
7.51 p. m. to 12.58 a. m.	29.0	6.0323	11.6083	5.5760	.0008	5.5768	351.50	1.0036	.40	.04	1,967.26
12.58 a. m. to 2 a. m.	28.0	6.2820	12.0880	5.8060	.0006	5.8066	51.00	1.0034	.30	......	297.14
2 a. m. to 3.08 a. m.	27.0	6.6006	13.5171	6.9165	.0004	6.9169	41.00	1.0030	.20	......	284.44
3.08 a. m. to 6 a. m.	29.0	5.9584	11.1751	5.2167	.0008	5.2175	220.50	1.0037	.40	.03	1,154.69
											4,393.98
Latent heat of water vapor											1,139.76
Correction for feed, water, excreta, and vessels											−11.41
Total heat											5,522.33
Subperiod 4.											
6 a. m. to 9.40 a. m.	29.0	6.0129	10.9675	4.9546	.0008	4.9554	279.00	1.0037	.40	.04	1,387.63
9.40 a. m. to 6 p. m.	29.0	6.1229	11.2345	5.1116	.0008	5.1124	602.00	1.0031	.40	.08	3,087.13
											4,474.76
Latent heat of water vapor											1,116.73
Correction for feed, water, excreta, and vessels											+14.07
Total heat											5,605.56

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current. Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.	Total water.	Average specific heat of water.	Heat produced in absorbers. Difference of pressure.	Equivalent heat.	Total heat, calories at 20°.
PERIOD II*a*.											
Subperiod 1.		°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*		*Cm.*	*Cal.*	
6 p. m. to 7.23 p. m.	28.0	5.0676	12.4276	7.3600	+0.0006	7.3606	67.50	1.0037	0.30	......	498.68
7.23 p. m. to 2.36 a. m.	29.0	4.1681	9.6580	5.4899	.0008	5.4907	517.50	1.0046	.40	0.07	2,854.44
2.36 a. m. to 3.04 a. m.	28.0	3.9163	9.6438	5.7275	.0006	5.7281	26.00	1.0044	.30	......	149.58
3.04 a. m. to 5.01 a. m.	27.0	4.5355	12.4741	7.9386	.0004	7.9390	62.00	1.0038	.20	......	494.09
5.01 a. m. to 6 a. m.	29.0	3.4421	9.3100	5.8679	.0008	5.8687	73.00	1.0049	.40	.01	430.50
											4,427.29
Latent heat of water vapor											1,343.90
Correction for feed, water, excreta, and vessels											−5.28
Total heat											5,765.91
Subperiod 2											
6 a. m. to 9.41 a. m.	29.0	3.2498	8.4346	5.1848	.0008	5.1856	277.00	1.0052	.40	.03	1,443.85
9.41 a. m. to 12.46 p. m.	27.0	4.1857	11.9750	7.7893	.0004	7.7897	102.00	1.0040	.20	......	797.73
12.46 p. m. to 2.46 p. m.	29.0	3.5490	9.6357	6.0867	.0008	6.0875	140.00	1.0048	.40	.02	856.32
2.46 p. m. to 4.29 p. m.	27.0	4.8046	12.9669	8.1623	.0004	8.1627	50.50	1.0037	.20	......	413.74
4.29 p. m. to 6 p. m.	29.0	3.9145	9.8682	5.9537	.0008	5.9545	105.83	1.0046	.40	.01	633.05
											4,144.69
Latent heat of water vapor											1,418.15
Correction for feed, water, excreta, and vessels											+76.44
Total heat											5,639.28
Subperiod 3.											
6 p. m. to 8.55 p. m.	29.0	3.8551	9.9025	6.0474	.0008	6.0482	198.00	1.0046	.40	.02	1,203.03
8.55 p. m. to 9.23 p. m.	27.0	4.6557	12.5771	7.9214	.0004	7.9218	12.00	1.0038	.20	......	95.42
9.23 p. m. to 10.42 p. m.	28.0	4.1560	11.2200	7.0640	.0006	7.0646	60.00	1.0042	.30	......	425.66
10.42 p. m. to 2.05 a. m.	29.0	3.5025	9.7694	6.2669	.0008	6.2677	230.00	1.0048	.40	.03	1,448.46
2.05 a. m. to 2.35 a. m.	28.0	3.8671	10.0114	6.1443	.0006	6.1449	26.00	1.0046	.30	......	160.50
2.35 a. m. to 4.33 a. m.	27.0	4.6323	13.2696	8.6373	.0004	8.6377	61.00	1.0037	.20	......	528.85
4.33 a. m. to 6 a. m.	29 0	3.4147	9.2357	5.8210	.0008	5.8218	108.75	1.0050	.40	.01	636.28
											4,498.20
Latent heat of water vapor											1,407.70
Correction for feed, water, excreta, and vessels											−3.94
Total heat											5,901.96
Subperiod 4.											
6 a. m. to 8.12 a. m.	29.0	3.4053	8.9379	5.5326	.0008	5.5334	160.00	1.0050	.40	.02	889.75
8.12 a. m. to 9.48 a. m.	27.0	4.7396	13.1496	8.4100	.0004	8.4104	46.00	1.0037	.20	......	388.31
9.48 a. m. to 10.33 a. m.	28.0	4.0182	10.9500	6.9318	.0006	6.9324	34.00	1.0043	.30	......	236.72
10.33 a. m. to 10.36 a. m.	27.0	4.3700	11.9800	7.6100	.0004	7.6104	1.00	1.0040	.20	......	7.64
10.36 a. m. to 1.07 p. m.	29.0	3.7216	9.6248	5.9032	.0008	5.9040	177.75	1.0047	.40	.02	1,054.01
1.07 p. m. to 1.42 p. m.	27.0	5.1844	12.5688	7.3844	.0004	7.3848	17.25	1.0037	.20	......	127.86
1.42 p. m. to 2.49 p. m.	28.0	4.7962	11.0456	6.2494	.0006	6.2500	56.00	1.0040	.30	......	351.40
2.49 p. m. to 6 p. m.	29.0	4.8045	9.9883	5.1838	.0008	5.1846	239.00	1.0043	.40	.03	1,244.42
											4,300.11
Latent heat of water vapor											1,396.04
Correction for feed, water, excreta, and vessels											+25.76
Total heat											5,721.91

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, calories at 20°.
		Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD IIIa.											
Subperiod 1.		°C.	°C.	°C.	°C.	°C.	Liters.		Cm.	Cal.	
6 p. m. to 8.57 p. m.	29.0	6.4284	11.4346	5.0062	+0.0008	5.0070	215.00	1.0035	0.40	0.03	1,080.24
8.57 p. m. to 9.23 p. m.	28.0	6.3200	12.2583	5.9383	.0006	5.9389	21.00	1.0034	.30	......	125.14
9.23 p. m. to 9.36 p. m.	27.0	6.6400	13.1300	6.4900	.0004	6.4904	5.50	1.0029	.20	......	35.80
9.36 p. m. to 2.53 a. m.	29.0	5.6846	11.3675	5.6829	.0008	5.6837	351.50	1.0037	.40	.04	2,005.17
2.53 a. m. to 4.24 a. m.	27.0	6.1169	13.7538	7.6369	.0004	7.6373	47.00	1.0028	.20	......	359.95
4.24 a. m. to 4.55 a. m.	28.0	5.7100	12.2987	6.5887	.0006	6.5893	26.00	1.0035	.30	......	171.92
4.55 a. m. to 4.58 a. m.	27.0	5.7000	12.2000	6.5000	.0004	6.5004	1.50	1.0035	.20	......	9.78
4.58 a. m. to 6 a. m.	29.0	5.2827	10.6780	5.3953	.0008	5.3961	75.50	1.0040	.40	.01	409.02
											4,197.02
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,390.93
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−.98
Total heat	....	......	......	......	......	......	......	......	......	......	5,586.97
Subperiod 2.											
6 a. m. to 8.31 a. m.	29.0	4.1684	10.6034	5.2581	.0008	5.2589	178.00	1.0040	.40	.02	939.80
8.31 a. m. to 9.16 a. m.	27.0	6.5208	13.7475	4.2267	.0004	4.2271	22.00	1.0030	.20	......	93.27
9.16 a. m. to 10.10 a. m.	27.5	6.2800	13.5908	7.3108	.0005	7.3113	34.50	1.0031	.25	......	253.02
10.10 a. m. to 11.46 a. m.	29.0	5.4408	11.2941	5.8533	.0008	5.8541	110.50	1.0038	.40	.01	649.32
11.46 a. m to 12.06 p. m.	27.0	6.1020	13.4140	7.3120	.0004	7.3124	10.00	1.0032	.20	......	73.35
12.06 p. m. to 12.32 p. m.	27.5	6.0886	13.3714	7.2828	.0005	7.2833	17.00	1.0032	.25	......	124.21
12.32 p. m. to 1.31 p. m.	27.0	6.4521	14.2535	7.8014	.0004	7.8018	28.00	1.0030	.20	......	219.10
1.31 p. m. to 2.27 p. m.	27.5	6.2457	13.1750	6.9293	.0005	6.9298	38.00	1.0031	.25	......	264.14
2.27 p. m. to 5.46 p. m.	29.0	5.9192	11.4074	5.4882	.0008	5.4890	230.50	1.0036	.40	.29	1,269.47
5.46 p. m. to 6 p. m.	27.0	6.4500	12.5867	6.1367	.0004	6.1371	7.50	1.0032	.20	......	46.17
											3,931.85
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,351.83
Correction for feed water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	+39.23
Total heat	....	......	......	......	......	......	......	......	......	......	5,322.91
Subperiod 3.											
6 p. m. to 7.46 p. m.	29.0	6.0941	11.6382	5.5441	.0008	5.5449	119.00	1.0036	.40	.01	662.20
7.46 p. m. to 8.23 p. m.	27.0	6.6267	13.5767	6.9500	.0004	6.9504	20.50	1.0030	.20	......	142.91
8.23 p. m. to 9.20 p. m.	27.5	6.4292	13.2823	6.8531	.0005	6.8536	41.50	1.0031	.25	......	284.30
9.20 p. m. to 9.54 p. m.	29.0	6.0600	11.6722	5.6122	.0008	5.6130	39.00	1.0036	.40	.01	219.68
9.54 p. m. to 10.24 p. m.	30.0	5.8562	10.6737	4.8175	.0010	4.8185	47.00	1.0038	.50	.01	227.32
10.24 p. m. to 11.22 p. m.	27.5	6.4693	13.6950	7.2257	.0005	7.2262	33.00	1.0030	.25	......	239.17
11.22 p. m. to 11.58 p. m.	28.0	6.0555	12.9766	6.9211	.0006	6.9217	27.00	1.0033	.30	......	187.50
11.58 p. m. to 12.22 a. m.	29.0	5.5767	11.6950	6.1183	.0008	6.1191	29.00	1.0037	.40	......	178.11
12.22 a. m. to 12.25 a. m.	30.0	5.5000	11.2200	5.7200	.0010	5.7210	2.50	1.0038	.50	......	14.35
12.25 a. m. to 2.09 a. m.	27.5	5.8604	13.6731	7.8127	.0005	7.8132	62.50	1.0032	.25	......	489.88
2.09 a. m. to 2.18 a. m.	29.0	5.2300	12.1500	6.9200	.0008	6.9208	10.00	1.0037	.40	......	69.46
2.18 a. m. to 3.04 a. m.	30.0	4.6850	10.0817	5.3967	.0010	5.3977	67.00	1.0043	.50	.01	363.19
3.04 a. m. to 4.59 a. m.	27.5	5.0235	12.5089	7.4854	.0005	7.4859	75.00	1.0037	.25	......	563.52
4.59 a. m. to 5.34 a. m.	30.0	4.1700	10.0089	5.8389	.0010	5.8399	46.00	1.0045	.50	.01	269.83
5.34 a. m. to 5.44 a. m.	29.0	4.1950	10.1000	5.9050	.0008	5.9058	10.50	1.0045	.40	......	62.29
5.44 a. m. to 6 a. m.	27.0	4.8325	12.4875	7.6550	.0004	7.6554	7.25	1.0038	.20	......	55.71
											4,029.42
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,294.10
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	+.96
Total heat	....	......	......	......	......	......	......	......	......	......	5,234.48

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current. Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.	Total water.	Average specific heat of water.	Heat produced in absorbers. Difference of pressure.	Equivalent heat.	Total heat, calories at 20°.
PERIOD III*a*—Cont'd.											
Subperiod 4.		°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*		*Cm.*	*Cal.*	
6 a. m. to 7.16 a. m.	29.0	4.1684	10.7689	6.6005	0.0008	6.6013	82.00	1.0043	0.40	0.01	543.62
7.16 a. m. to 9.30 a. m.	28.0	4.5500	12.0151	7.4651	.0006	7.4657	102.00	1.0039	.30	.01	764.46
9.30 a. m. to 10.07 a. m.	27.0	5.3700	13.8244	8.4544	.0004	8.4548	16.00	1.0034	.20	......	135.73
10.07 a. m. to 10.46 a. m.	27.5	5.1550	13.3570	8.2020	.0005	8.2025	23.00	1.0032	.25	......	189.26
10.46 a. m. to 11.36 a. m.	27.0	5.5208	14.0777	8.5569	.0004	8.5573	23.00	1.0033	.20	......	197.46
11.36 a. m. to 12.22 p. m.	28.0	4.9227	13.1027	8.1800	.0006	8.1806	33.00	1.0036	.30	......	270.93
12.22 p. m. to 1.37 p. m.	29.0	4.6826	11.8158	7.1332	.0008	7.1340	68.00	1.0040	.40	.01	487.04
1.37 p. m. to 1.58 p. m.	27.0	5.4100	13.4140	8.0040	.0004	8.0044	7.95	1.0034	.20	......	62.24
1.58 p. m. to 3.56 p. m.	27.5	5.8213	13.9290	8.1077	.0005	8.1082	61.25	1.0032	.25	......	498.21
3.56 p. m. to 5.27 p. m.	29.0	5.2195	11.3545	6.1350	.0008	6.1358	96.00	1.0039	.40	.01	591.32
5.27 p. m. to 6 p. m.	28.5	5.4100	11.7100	6.3000	.0007	6.3007	28.75	1.0037	.35	......	181.81
											3,922.08
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,399.81
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	+29.07
Total heat	....	......	......	......	......	......	......	......	......	......	5,350.96
PERIOD I*b*.											
Subperiod 1.											
6 p. m. to 6.23 p. m.	45.0	3.1883	4.2750	1.0867	+0.0162	1.1029	148.00	1.0064	9.15	.43	163.84
6.23 p. m. to 12.11 a. m.	47.0	2.8406	3.9274	1.0868	.0196	1.1064	2,236.00	1.0067	10.25	7.27	2,492.75
12.11 a. m. to 1.14 a. m.	49.0	2.8613	3.9106	1.0493	.0230	1.0723	416.00	1.0067	11.25	1.48	447.58
1.14 a. m. to 6. a. m.	51.0	2.8275	3.8159	.9884	.0266	1.0150	1,969.00	1.0062	12.25	7.60	2,003.33
											5,107.50
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	735.76
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−15.27
Total heat	....	......	......	......	......	......	......	......	......	......	5,827.99
Subperiod 2.											
6 a. m. to 6.20 a. m.	51.0	......	......	......	......	......	130.00	......	......	......	......
6.20 a. m. to 8.28 a. m.	85.0	......	......	......	......	......	114.00	......	......	......	......
8.28 a. m. to 9.10 a. m.	50.0	6.2910	7.0260	.7350	.0248	.7598	298.00	1.0046	11.75	1.09	226.37
9.10 a. m. to 9.28 a. m.	42.0	6.6400	7.6620	1.0220	.0122	1.0342	88.00	1.0043	7.00	.20	91.20
9.28 a. m. to 11.37 a. m.	38.0	4.2800	5.9606	1.6806	.0074	1.6880	470.00	1.0055	4.00	.60	792.12
11.37 a. m. to 12.21 p. m.	42.0	3.3818	4.8290	1.4472	.0122	1.4594	200.00	1.0061	7.00	.44	293.22
12.21 p. m. to 1.46 p. m.	38.0	4.0405	5.8333	1.7928	.0074	1.8002	300.00	1.0056	4.00	.38	542.70
1.46 p. m. to 3.25 p. m.	39.0	2.5652	4.9284	2.3632	.0086	2.3718	300.00	1.0064	4.75	.45	715.64
3.25 p. m. to 4 p. m.	40.0	2.2245	4.7922	2.5677	.0098	2.5775	100.00	1.0066	5.60	.18	259.27
4 p. m. to 4.18 p. m.	41.0	2.2325	4.8800	2.6475	.0110	2.6585	44.00	1.0066	6.30	.09	117.65
4.18 p. m. to 4.28 p. m.	43.0	1.9650	4.6700	2.7050	.0134	2.7184	32.00	1.0067	7.75	.08	87.49
4.28 p. m. to 4.43 p. m.	45.0	1.7625	4.4625	2.7000	.0162	2.7162	35.00	1.0068	9.15	.10	95.61
4.43 p. m. to 6 p. m.	48.0	2.0400	4.7179	2.6779	.0213	2.6992	200.25	1.0066	10.75	.68	543.40
											3,764.67
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	826.05
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−19.09
Total heat	....	......	......	......	......	......	......	......	......	......	4,571.63
Subperiod 3.											
6 p. m to 5.02 a. m.	48.0	2.8490	4.2419	1.3929	.0213	1.4142	3,320.00	1.0065	10.75	11.43	4,714.23
5.02 a. m. to 5.46 a. m.	50.0	2.6891	4.1482	1.4591	.0248	1.4839	232.00	1.0066	11.75	.85	345.69
5.46 a. m. to 6. a. m.	49.0	2.1633	3.5967	1.4334	.0266	1.4600	68.00	1.0070	11.25	.24	99.73
											5,159.65

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, calories at 20°.
		Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD I*b*—Cont'd.											
Subperiod 3.—Cont'd.											
		°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*		*Cm.*	*Cal.*	
Latent heat of water vapor											815.39
Correction for feed, water, excreta, and vessels											−18.09
Total heat											5,956.95
Subperiod 4.											
6 a. m. to 9.31 a. m.	49.0	3.5877	5.0707	1.4830	0.0230	1.5060	932.00	1.0062	11.25	3.32	1,408.57
9.31 a. m. to 10.10 a. m.	47.0	4.2560	5.7180	1.4620	.0196	1.4816	168.00	1.0056	10.25	.55	249.75
10.10 a. m. to 11.38 a. m.	43.0	3.9250	5.8359	1.9109	.0134	1.9243	300.00	1.0057	7.75	.74	579.84
11.38 a. m. to 1 p. m.	43.0	3.2415	5.8280	2.5865	.0134	2.5999	200.00	1.0059	7.75	.49	522.56
1 p. m. to 6 p. m.	47.0	2.3776	5.2708	2.8932	.0196	2.9128	718.00	1.0064	10.25	2.33	2,102.45
											4,863.17
Latent heat of water vapor											887.11
Correction for feed, water, excreta, and vessels											−10.32
Total heat											5,739.96
PERIOD II*b*.											
Subperiod 1.											
6 p. m. to 6.35 p. m.	32.0	2.5389	5.3778	2.8389	+0.0020	2.8409	78.00	1.0063	1.00	.02	222.97
6.35 p. m. to 6.55 p. m.	33.0	2.4440	4.9800	2.5360	.0024	2.5384	55.00	1.0064	1.50	.03	140.48
6.55 p. m. to 7.17 p. m.	34.0	2.3800	4.6200	2.2400	.0032	2.2432	67.00	1.0066	2.00	.04	151.25
7.17 p. m. to 11.05 p. m.	35.0	2.4491	4.4033	1.9542	.0040	1.9582	800.00	1.0066	2.50	.63	1,576.27
11.05 p. m. to 1.51 a. m.	36.0	2.2898	4.1261	1.8363	.0050	1.8413	645.00	1.0068	3.00	.61	1,195.10
1.51 a. m. to 1.56 a. m.	33.0	2.2650	4,0600	1.7950	.0024	1.7974	18.00	1.0068	1.50	,01	32.56
1.56 a. m. to 3.29 a. m.	36.0	2.1744	3.9557	1.7813	.0050	1.7863	370.00	1.0068	3.00	.35	665.08
3.29 a. m. to 3.49 a. m.	33.0	2.2875	4.1850	1.8975	.0024	1.8999	50.00	1.0067	1.50	.02	95.61
3.49 a. m. to 4.39 a. m.	34.0	2.2138	3.8938	1.6800	.0032	1.6832	160.00	1.0069	2.00	.10	271.07
4.39 a. m. to 4.53 a. m.	32.0	2.3300	4.4766	2.1466	.0020	2.1486	31.00	1.0066	1.00	.01	67.04
4.53 a. m. to 5.46 a. m.	30.0	2.5114	5.5164	3.0050	.0010	3.0060	85.00	1.0063	50	.01	257.11
5.46 a. m. to 5.52 a. m.	33.0	2.1800	4.8500	2.6700	.0024	2.6724	16.00	1.0066	1.50	.01	43.03
5.52 a. m. to 5.57 a. m.	35.0	2.0500	4.1300	2.0800	.0040	2.0840	23.00	1.0069	2.50	.02	48.24
5.57 a. m. to 6 a. m.	37.0	1.9850	3.8450	1.8600	.0062	1.8662	13.00	1.0069	3.50		24.43
											4,790.24
Latent heat of water vapor											997.05
Correction for feed, water, excreta, and vessels											−14.23
Total heat											5,773.06
Subperiod 2.											
6 a. m. to 7.33 a. m.	37.0	1.9696	3.7492	1.7796	.0062	1.7858	383.00	1.0070	3.50	.43	688.32
7.33 a. m. to 1.14 p. m.	36.0	2.4865	4.1986	1.7121	.0050	1.7171	1,238.00	1.0067	3.00	1.18	2,138.83
1.14 p. m. to 1.29 p. m.	34.0	2.7550	4.6325	1.8775	.0032	1.8807	44.00	1.0064	2.00	.03	83.25
1.29 p. m. to 1.43 p. m.	33.0	2.7833	4.7466	1.9633	.0024	1.9657	35.00	1.0064	1.50	.02	69.22
1.43 p. m. to 2.06 p. m.	32.0	2.8850	5.1383	2.2533	.0020	2.2553	46.50	1.0048	1.00	.01	105.36
2.06 p. m. to 3.26 p. m.	30.0	3.2140	6.4190	3.2050	.0010	3.2060	100.50	1.0057	.50	.02	324.02
3.26 p. m. to 6 p. m.	37.0	2.7226	5.4550	1.7324	.0062	1.7386	597.50	1.0062	3.50	.66	1,044.59
											4,453.59
Latent heat of water vapor											976.42
Correction for feed, water, excreta, and vessels											−129.24
Total heat											5,300.77

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, calories at 20°.
		Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD II*b*—Cont'd.											
Subperiod 3.		°C	°C	°C	°C	°C	Liters.		Cm.	Cal.	
6 p. m. to 7.59 p. m.	37.0	2.5843	4.2926	1.7083	0.0062	1.7145	472.00	1.0066	3.50	0.52	814.07
7.59 p. m. to 10.38 p. m.	34.0	2.5803	4.4635	1.8832	.0032	1.8864	454.00	1.0065	2.00	.29	861.70
10.38 p. m. to 10.56 p. m.	37.0	2.4100	4.1220	1.7120	.0062	1.7182	74.00	1.0069	3.50	.08	127.94
10.56 p. m. to 11.07 p. m.	39.0	2.3650	3.9200	1.5550	.0086	1.5636	55.00	1.0068	4.75	.08	86.50
11.07 p. m. to 11.42 p. m.	41.0	2.3478	3.7645	1.4167	.0110	1.4277	189.00	1.0069	6.30	.38	271.32
11.42 p. m. to 12.42 a. m.	34.0	2.4747	4.4027	1.9280	.0032	1.9312	184.00	1.0066	2.00	.12	357.57
12.42 a. m. to 1.51 a. m.	32.0	2.4647	4.8665	2.4018	.0020	2.4038	158.00	1.0065	1.00	.05	382.22
1.51 a. m. to 2.02 a. m.	37.0	2.2533	4.3900	2.1367	.0062	2.1429	23.00	1.0067	3.50	.03	49.59
2.02 a. m. to 2.48 a. m.							2.00				
2.48 a. m. to 3.16 a. m.	37.0	3.2729	6.2943	3.0214	.0062	3.0276	89.00	1.0058	3.50	.10	270.92
3.16 a. m. to 3.34 a. m.	38.0	3.0420	5.2260	2.1840	.0074	2.1914	62.00	1.0062	4.00	.08	136.63
3.34 a. m. to 5.17 a. m.	40.0	2.6096	3.9588	1.3492	.0098	1.3590	538.00	1.0067	5.60	.96	735.08
5.17 a. m. to 6 a. m.	42.0	2.3820	3.7540	1.3720	.0122	1.3842	240.00	1.0068	7.00	.53	333.94
											4,427.48
Latent heat of water vapor											1,058.32
Correction for feed, water, excreta, and vessels											−25.61
Total heat											5,460.19
Subperiod 4.											
6 a. m. to 7.10 a. m.	42.0	2.3500	3.7078	1.3578	.0122	1.3700	409.00	1.0069	7.00	.91	563.29
7.10 a. m. to 8.11 a. m.	40.0	2.4373	3.8406	1.4033	.0098	1.4131	306.00	1.0068	5.60	.55	434.80
8.11 a. m. to 8.59 a. m.	38.0	2.5150	4.0800	1.5650	.0074	1.5724	207.00	1.0067	4.00	.26	327.41
8.59 a. m. to 9.16 a. m.	33.0	2.6275	4.6525	2.0250	.0024	2.0274	35.00	1.0065	1.50	.02	71.40
9.16 a. m. to 10.26 a. m.	32.0	2.7522	5.0372	2.2850	.0020	2.2870	166.50	1.0063	1.00	.53	382.65
10.26 a. m. to 1.24 p. m.	37.0	2.6136	4.3141	1.7005	.0062	1.7067	700.50	1.0066	3.50	.78	1,202.65
1.24 p. m. to 1.26 p. m.	35.0	2.8500	4.3900	1.5400	.0040	1.5440	6.00	1.0065	2.50		9.32
1.26 p. m. to 2.20 p. m.	31.0	3.1177	5.6615	2.5438	.0012	2.5450	98.00	1.0056	.75	.02	250.79
2.20 p. m. to 2.40 p. m.	37.0	2.8380	4.6020	1.7640	.0062	1.7702	78.00	1.0064	3.50	.09	138.87
2.40 p. m. to 2.53 p. m.	39.0	2.8075	4.2975	1.4900	.0086	1.4986	64.00	1.0065	4.75	.10	96.43
2.53 p. m. to 6 p. m.	41.0	2.7161	3.9972	1.2811	.0110	1.2921	1,003.75	1.0066	6.30	2.00	1.303.50
											4,781.11
Latent heat of water vapor											1,049.46
Correction for feed, water, excreta, and vessels											−42.09
Total heat											5,788.48
PERIOD III*b*.											
Subperiod 1.											
6 p. m. to 10.27 p. m.	35.0	2.4247	4.8101	2.3854	+0.0040	2.3894	762.50	1.0065	2.50	.60	1,833.76
10.27 p. m. to 10.45 p. m.	33.0	2.5340	4.8140	2.2800	.0024	2.2824	43.50	1.0065	1.50	.02	99.91
10.45 p. m. to 12.21 a. m.	30.0	2.9704	6.4647	3.4943	.0010	3.4953	135.00	1.0058	.50	.02	474.58
12.21 a. m. to 12.38 a. m.	35.0	2.6560	5.2800	2.6240	.0040	2.6280	46.00	1.0063	2.50	.04	121.61
12.38 a. m. to 2.05 a. m.	37.0	2.5641	4.7613	2.1972	.0062	2.2034	284.00	1.0065	3.50	.32	629.51
2.05 a. m. to 3.31 a. m.	32.0	2.6633	5.2290	2.5657	.0020	2.5677	177.00	1.0063	1.00	.06	457.29
3.31 a. m. to 4.18 a. m.	35.0	2.3025	4.7758	2.4733	.0040	2.4773	139.00	1.0066	2.50	.11	346.51
4.18 a. m. to 6 a. m.	36.0	2.1496	4.3460	2.1964	.0050	2.2014	315.34	1.0067	3.00	.30	698.54
											4,661.11
Latent heat of water vapor											1,039.83
Correction for feed, water, excreta, and vessels											− 17.80
Total heat											5,683.14

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, calories at 20°.
		Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD III*b*—Cont'd.											
Subperiod 2.		°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*		*Cm.*	*Cal.*	
6 a. m. to 10.33 a. m.	36.0	2.4933	4.5211	2.0278	0.0050	2.0328	839.00	1.0066	3.00	0.80	1,715.98
10.33 a. m. to 11.34 a. m.	31.0	3.0787	5.7440	2.6653	.0012	2.6665	106.00	1.0060	.75	.03	284.32
11.34 a. m. to 12.25 p. m.	30 0	3.1423	6.2508	3.1085	.0010	3.1095	76.00	1.0058	.50	.01	237.68
12.25 p. m. to 12.33 p. m.	29.0	3.2250	6.7150	3.4900	.0008	3.4908	8.50	1.0057	.40	......	29.84
12.33 p. m. to 1.47 p. m.	34.0	2.7544	5.1600	2.4056	.0032	2.4088	190.50	1.0063	2.00	.12	461.65
1.47 p. m. to 1.54 p. m.	33.0	2.7450	4.9400	2.1950	.0024	2.1974	16.00	1.0063	1.50	......	35.38
1.54 p. m. to 2.44 p. m.	29.0	3.1108	6.8450	3.7342	.0008	3.7350	57.50	1 0057	.40	......	215.99
2.44 p. m. to 6 p. m.	33.0	2.7171	5.4371	2.7200	.0024	2.7224	458.50	1.0062	1.50	.22	1,255.74
											4,236.58
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	960.73
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−82.25
Total heat	....	......	......	......	......	......	......	......	......	......	5,115.06
Subperiod 3.											
6 p. m. to 8.07 p. m.	33.0	2.7809	5.5312	2.7503	.0024	2.7527	293.00	1.0062	1.50	.14	811.40
8.07 p. m. to 9.30 p. m.	29.0	3.2067	7.3129	4.1062	.0008	4.1070	95.50	1.0055	.40	.01	394.36
9.30 p. m. to 9.36 p. m.	33.0	2.8800	6.1000	3.2200	.0024	3.2224	11.50	1.0060	1.50	......	37,28
9.36 p. m. to 10.02 p. m.	35.0	2.7743	5.3029	2.5286	.0040	2.5326	73.50	1.0062	2.50	.06	187.24
10.02 p. m. to 1.25 a. m.	37.0	2.8249	4.9000	2.0751	.0062	2.0813	663.00	1.0063	3.50	.74	1,387.85
1.25 a. m. to 2.58 a. m.	32.0	3.2100	5.9000	2.6900	.0020	2.6920	178.50	1.0059	1.00	.06	483.30
2.58 a. m. to 3.14 a. m.	35.0	3.0925	5.4850	2.3925	.0040	2.3965	47.50	1.0061	2.50	.04	114.48
3.14 a. m. to 3.47 a. m.	37.0	2.8613	5.0451	2.1838	.0062	2.1900	90.00	1.0063	3.50	.10	198.24
3.47 a. m. to 5.14 a. m.	32.0	2.6382	5.3873	2.7491	.0020	2.7510	169.50	1.0063	1.00	.05	469.18
5.14 a. m. to 5.27 a. m.	30.0	2.4400	5.9600	3.5200	.0010	3.5210	7.00	1.0062	.50	......	24.80
5.27 a. m. to 5.44 a. m.	28.0	2.7725	7.7125	4.9400	.0006	4.9406	23.00	1.0056	.30	......	114.27
5.44 a. m. to 6 a. m.	35.0	2.0300	5.2225	3.1925	.0040	3.1965	43.25	1.0065	2.50	.03	139.12
											4,361.52
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,002.44
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−18.85
Total heat	....	......	......	......	......	......	......	......	......	......	5,345.11
Subperiod 4.											
6 a. m. to 9.04 a. m.	37.0	1.9639	4.1550	2.1911	.0062	2.1973	575.50	1.0069	3.50	.64	1,272.63
9.04 a. m. to 9.18 a. m.	36.0	2.1700	4.1975	2.0275	.0050	2.0325	40.50	1.0068	3.00	.04	82.83
9.18 a. m. to 11.28 a. m.	29.0	3.0169	7.1572	4.1403	.0008	4.1411	138.00	1.0056	.40	.02	574.65
11.28 a. m. to 1.43 p. m.	36.0	2.6065	4.9512	2.3447	.0050	2.3497	392.50	1.0064	3.00	.37	927.79
1.43 p. m. to 1.45 p. m.	29.0	2.6600	5.0300	2.3700	.0008	2.3708	1.00	1.0064	.40	......	2.38
1.45 p. m. to 6 p. m.	36.0	2.8551	5.0764	2.2213	.0050	2.2263	731.50	1.0063	3.00	.70	1,638.09
											4,498.37
Latent heat of water vapor	....	......	......	......	......	......	......	......	......	......	1,096.07
Correction for feed, water, excreta, and vessels	....	......	......	......	......	......	......	......	......	......	−32.73
Total heat	....	......	......	......	......	......	......	......	......	......	5,561.71

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